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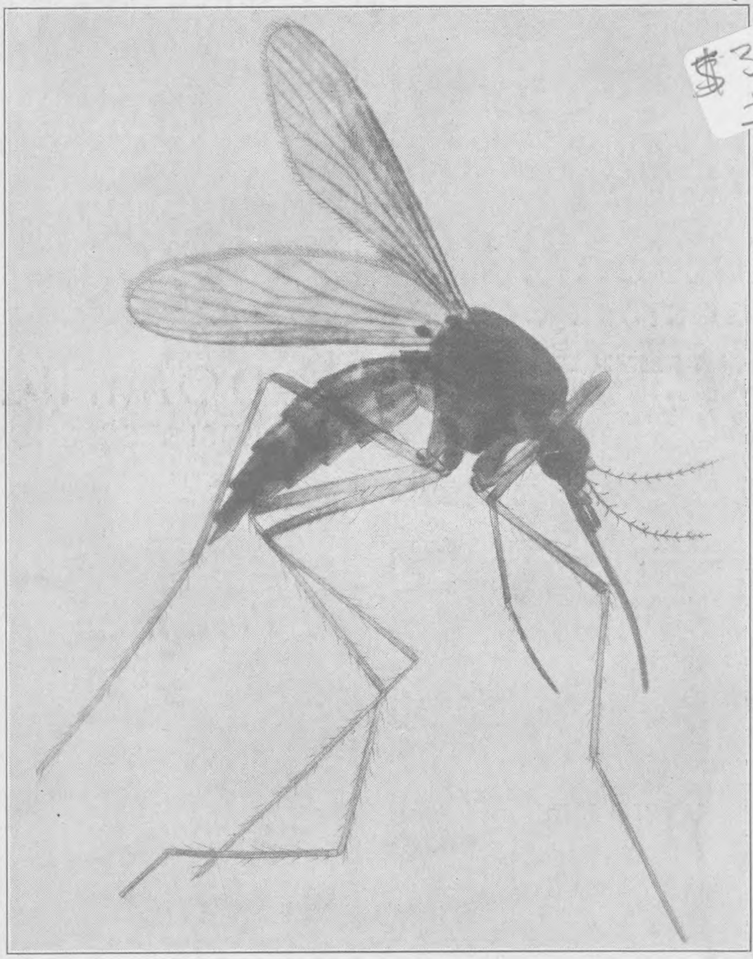
QUESTION MARK



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The Mosquito is suspected of carrying the so-called sleeping sickness

See Page 4—F. W. Jackson's "Manitoba's Encephalitis Epidemic—1941."

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December, 1941.

THE QUESTION MARK

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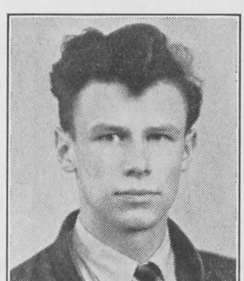

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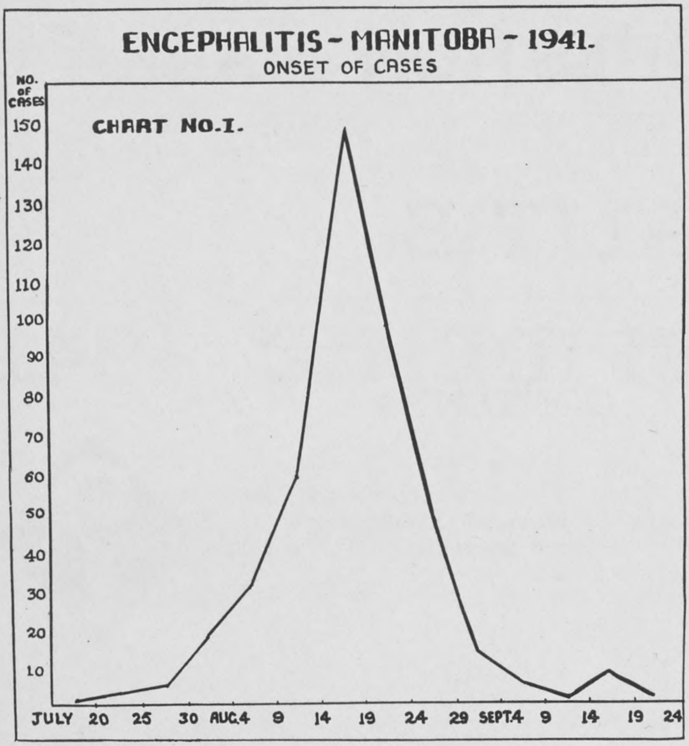


MANITOB

by F. W. JACKSON
M.D. (Man.) D.P.H. (Tor.)

ENCEPHALITIS, or as it is sometimes wrongly called, sleeping sickness, is no new disease in this Province. Epidemics have been reported in 1919-20 and in 1926. A few cases also were reported in 1938. The epidemic in Manitoba this year coincided with similar epidemics in Minnesota, the Dakotas, and Southern Saskatchewan. Altogether in this epidemic area not less than some 5,000 persons contracted the illness and probably some 500 people died.

Epidemic encephalitis has been known for over a quarter of a century and was first described by Economo in Austria in 1917, and study since that time has revealed that there are at least five distinct varieties of the disease, distinct not so much as to clinical findings but absolutely distinct as to causative agent. These are called:

1. Vienna type. The original described.
2. Japanese type, described in Japan in 1924.
3. St. Louis type, which occurred in St. Louis City and County first in 1933 and again in 1937.
4. Eastern Equine type which caused epidemics in the eastern seaboard states in 1931 and 1938.
5. Western Equine type. This disease has been known in horses since 1930 and in humans since 1932.

It is this last type, the Western Equine, which we have had to deal with in Manitoba this year.

All cases of the disease reported were fairly true to type and presented a uniform picture, the symptoms varying usually only in degree. From seven to fourteen days after infection of an individual the disease becomes apparent.

"The onset is usually quite sudden, with headache, fever and malaise. Chills or chilly sensations appear quite frequently. In one to two days, occasionally longer, the patient usually feels sick enough to stay in bed and at this time drowsiness and fever are the most pronounced symptoms. In severe cases the fever usually continues to rise and stupor or coma appear. There may be a period of marked restlessness. In cases of any severity, the patient is mentally confused. The only common physical findings are moderate

A'S ENCEPHALITIS EPIDEMIC, 1941

The Deputy Health Minister reviews the so-called "Sleeping Sickness" Epidemic and speculates as to its recurrence.

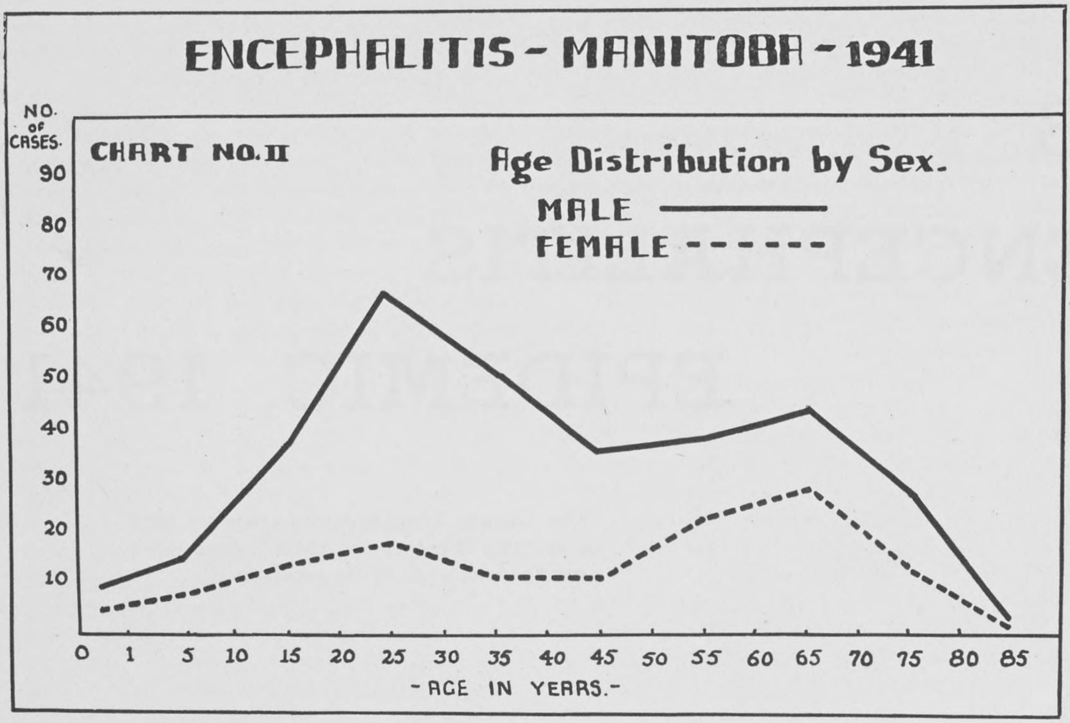
stiffness of the neck and tremor of the lips, tongue and hands. Some report quite frequent absence of the abdominal reflexes. The only laboratory finding of note is an increased spinal fluid cell count. The increase is usually moderate, 30 to 400, with lymphocytes usually predominating. The acute illness lasts ten to fourteen days as a rule. Convalescence may be prolonged because of a feeling of weakness. Recovery is usually complete. Sequelae appear to be unusual and have been reported chiefly in children in whom severe mental retardation and paralysis may occur."* The marked drowsiness has been responsible for the misnomer of sleeping sickness. This term should not be used in connection with any of the types of encephalitis as it really is the common name for a tropical disease caused by a parasite.

In Manitoba our records indicate that the first case occurred this year on July 18th. The disease did not really become epidemic, however, until the first week in August and reached its peak by August the 19th, and then rapidly subsided. Altogether we have had reported in Manitoba up until November 10th, 484 cases with 65 deaths or a death rate of approximately 14%. The deaths from this disease will be greater in number than all the deaths from all communicable diseases excluding tuberculosis, so from the standpoint of Public Health the epidemic has been of major importance.

The epidemic has shown very definite characteristics which distinguish it from all other epidemics we have recorded in this Province. These distinguishing features are:

1. Suddenness of onset and suddenness of decline.
2. Age groups attacked. Every age group, but highest attack rates in order of cases reported were in age groups 20-29, 60-69, 50-59, and 30-39. For some unknown reason infants under one year of age also seemed to be particularly susceptible.
3. A preference for rural people instead

* "Minnesota Medicine" September, 1941.
"Minnesota Medicine" August, 1941.
"Minnesota Medicine" December, 1938.
U.S.A. Army Reports (Simmons).
Journal of the American Veterinary Association (Kelser).



of urban dwellers, four out of five cases occurring outside of Winnipeg.

4. A disease of male persons, three out of four persons being male.
5. Attacked chiefly male adult persons who worked outside.

In Manitoba most of the early cases occurred in the municipalities bordering on North Dakota and Minnesota although there was an odd case in the Winnipeg district during the first ten days of the epidemic. It would seem as if the epidemic spread from south to north fairly evenly from east to west. There were very few cases east of the Red River and few north of the Riding Mountains. In other words, the disease avoided the coniferous parts of the province and was well confined to the prairie farming communities. We think there are definite reasons for this peculiarity and these will be discussed later.

Chart No. 1 indicates the onset period of cases reported. One is immediately struck with the suddenness of the onset of the cases and sudden cessation of the epidemic. It would look as if the infection was scattered throughout our population all at the one time and as suddenly stopped. This chart represents the course of an epidemic which might be caused by a food and water infection of a population but we are pretty certain that infection of food and water was not the means by which the infection was spread.

Chart No. 2 indicates the age distribution by age and sex and it will be seen that although the age distribution is fairly constant in both sexes, that the male rates are consistently higher than the female. Over 63% of all the cases reported were over thirty years of age. In poliomyelitis (infantile paralysis) less than 3% of cases were over 30 years of age. The youngest case reported was under two months of age, and the oldest, ninety-three years of age.

Table No. 1 shows the distribution by ten-year age groups as between Winnipeg and the rest of the Province. One sees that in every age group and in both sexes more cases had country residence than city residence.

One may remark, no doubt we have had a very widespread and serious epidemic of encephalitis in man this year but can you

tell us why we had the epidemic? How was the disease spread and what can we do in future to prevent or control future possible epidemics?

Why did we have an epidemic of encephalitis, and why this year? Manitoba has had an epizootic disease amongst horses known as encephalomyelitis for the past ten years. This was epidemic in horses in 1937 and 1938. The virus of this disease in horses is the one which caused the epidemic in humans this year. If there had not been any disease in horses we would not likely have had this equine encephalitis in our human population. Since the horse encephalomyelitis became widespread there is a great deal of evidence to show that the virus causing the disease has become fairly widespread in other animals and birds both domesticated and wild, so that now probably there is plenty of the virus around amongst our normal animal and bird population to form a source of infection for men, providing there is some means of transmitting the infection from animal and bird to man, and, of course, the spread would have to be from the diseased animal to man.

In 1938, in man, twenty-five cases were reported, in 1939, thirteen cases, and in 1940, ten cases, and nearly all of these gave histories of close and direct contact with sick horses. It would seem that something for widespread distribution of infection was lacking, or that it was difficult to spread infection directly from horse to man. A great deal of experimental work has been carried out in reference to the possibility and probability of there being an insect vector which is responsible for carrying the infection from the infected animals and birds to man, and the general concensus of opinion now seems to be that a mosquito or mosquitoes are the offending insects.

William A. Riley, Ph. D., Chief of the Division of Entomology of the University of Minnesota, in a paper published in "Minnesota Medicine," December, 1938, sums up pretty correctly, we think, in part as follows:

"1. That the epidemiological evidence indicates that arthropod vectors play a role in the spread of encephalomyelitis to animals and to man

"2. Mosquitoes of the genus *Aedes* most nearly meet the requirements for this transmission and there is conclusive experimental evidence that they are

PROVINCE OF MANITOBA ENCEPHALITIS — 1914

October 4th, Inclusive

CASES BY SEX AND AGE GROUPS

	MALE			FEMALE			TOTALS		
Age Group	Winnipeg	All outside Wpg. proper.	Total Male Cases	Wpg.	All outside Wpg. proper	Total female cases	Total Wpg. Cases	Total outside Wpg. proper	TOTAL CASES
0-9	6	19	25	1	11	12	7	30	37
10-19	8	30	38	2	10	12	10	40	50
20-29	9	57	66	6	13	19	15	70	85
30-39	7	44	51	6	5	11	13	49	62
40-49	7	29	36	2	9	11	9	38	47
50-59	5	35	40	10	13	23	15	48	63
60-69	11	33	44	6	21	27	17	54	71
70-79	8	20	28	5	8	13	13	28	41
80-89	1	2	3	1	1	2	2	3	5
Unknown	0	3	3	0	0	0	0	3	3
	62	272	334	39	91	130	101	363	464

capable of taking up, incubating and increasing the virus, and then transmitting it to healthy laboratory animals and to horses.

"3. There is no satisfactory evidence that other arthropods are implicated, unless under very exceptional conditions.

"Difficulties in the way of accepting the theory that aedine mosquitoes are the most important carriers are:

"1. In spite of numerous attempts, infective mosquitoes have never been found under natural conditions.

"2. Our native aedine mosquitoes, and specifically, those shown to be potential carriers, do not winter as adults. Since diseased horses are infective to mosquitoes only in the first few days, there must be some other explanation of the survival of the infection over winter."

Carl M. Eklund, M.D., Senior Epidemiologist of the Division of Preventable Diseases, Minnesota Department of Health, in the same Journal in respect to mosquitoes, says:

"Four mosquitoes shown to transmit the western strain occur in Minnesota: *A. vexans, A. migromaculis, A. dorsalis, and A. taeniorhynchus.* Of these only *A. vexans* is a common mosquito."

All over the epidemic area during the past year one of the commonest varieties of mosquitoes before and during the epidemic was *Aedes vexans.* This particular variety is easily infected in the laboratory with the virus of the disease, and they become infective to animal and man after a five-day incubation period. They remain infective apparently during their lifetime for a period up to three months by actual test. Added to this definite evidence is the fact that the range of this particular mosquito is up to fifteen miles. This fact would explain partially at least the simultaneous widespread infection of humans.

If this mosquito is the means by which the infection is conveyed to man, and everything indicates that it is at least one of the means, where does it get the infection? At the present time, this we do not know. Many experiments have been carried out with the mosquito in nature and samples of them examined in the natural state have failed as yet to show evidence of infection. Most authorities think that the probable host for the virus in nature is a bird of some description. The reason for this is that the virus has been identified in several varieties of bird, the pigeon, the ring-neck pheasant, and this last year in North Dakota, in the common prairie chicken. The almost simultaneous occurrence of infection in widely scattered areas would seem to indicate that a bird is probably the most likely animal to fit the picture in view of the fact that birds can travel long distances in a short space of time.

However, a great deal more research is needed to establish the native animals and birds infected and also to try and establish how the infection gets from horses to these other hosts in nature, and to establish also whether or not we have to have an epidemic of the disease in the host before we can have the virus transmitted by mosquito from the native hosts to man.

I am sure many readers will wonder whether or not we are going to have more cases again next year. This is something nobody can tell. If the disease were to follow the usual pattern of infantile paralysis, we would expect to have a secondary epidemic next year with a fewer number of cases than we have had this year, but the method of spread of the two diseases seems to be entirely different so on this account we cannot base any predictions on what will happen with encephalitis during future years. One would think, however, that if we have conditions similar this coming year to what have been prevalent in 1941, there is a strong likelihood that we will have more cases. Then again, as the disease has become more or less widespread in the human being it may be possible that humans may be hosts for the virus and become carriers of the disease, and possibly in the course of time the method of spread of infection may change, partially at least, from an insect vector to a contact disease. Experimentation and research over many years are the only ways this problem will be solved.

Many will ask, too, what we can do to prevent the disease, and what may be done if it occurs to prevent death and disability. There are good prospects in reference to the prevention of the disease that an immunizing agent for man may be ultimately provided

which will be as effective as the immunizing agent they now use for the protection of horses against this disease. This is not as yet available, although experiments have been carried on in respect to its use which indicate that it may be quite probable that a 100% efficient immunizing agent may be available. Unfortunately, such an agent is only effective for a limited period of time, probably not more than from two to three years. It would seem, however, that as and when such an immunizing agent becomes available that it would be highly desirable that those persons who are most likely to be exposed to the infection, namely, males working outside, should take advantage of such an agent for protecting themselves against infection.

Lacking any immunization, the information gathered this year would indicate that it is highly desirable to take the following precautions:

1. Reduce exposure to mosquito bites to the minimum, either by the use of mosquito oil, netting, or other means;
2. Limit over-exertion as this seems to be a pre-disposing factor to the infection;
3. Limit exposure to sunlight. What this has to do with the infection we do not know but a detailed study of a great number of cases gives a history of increased exposure to sunlight. Probably this may have something to do with the reduction in the vitamin content of the body and leaving it more susceptible to any type of infection.

If one contracts the disease the only advice that can be given is that the individual should immediately go to bed, preferably in hospital; have competent medical attention, and remain in bed for a considerable period of time after the acute symptoms of the disease have subsided. We believe this will go a long way towards preventing the possibility of after-effects. It is quite possible that the next two or three years may see developed a serum or antitoxin which will be effectual in treatment.

We hope to be able during the course of this coming year to carry on a considerable amount of research work, particularly looking towards the finding of some host in nature and definitely establishing the means by which the disease is spread from this host to men.

One cannot leave the matter of research without pointing out with some degree of pride that to Manitoba goes the honour of first being able to isolate the virus of Western equine encephalitis from the spinal fluid of a victim of this disease. This was done by the staff at the Children's Hospital, Winnipeg.

SYNT PLAS

H. H. SAUNDERSON, M.Sc. (Man.)
Ph.D. (McGill),
Assistant Professor of Chemistry,
U. of Man.

A SPILLED bottle started the plastics industry. Back in the 1860's John Wesley Hyatt, a printer, had read an advertisement by the manufacturers of billiard equipment. Billiard balls had been made from the ivory of elephants' tusks, but the game was increasing in popularity far faster than the supply of elephants whose tusks were larger than two and seven-sixteenths inches in diameter. In order to avoid a shortage of material, the manufacturers announced a prize of $10,000.00 to anyone who would devise a suitable synthetic material. Hyatt had been turning this over in his mind when one day, after injuring his finger in the printing shop, he went to the first-aid cabinet to get some collodion to cover his wound. The man before him had carelessly allowed the bottle to fall over with the cork out, and all that remained was a tough horny crust on the edge of the cabinet. It wasn't any use for his finger, but Hyatt's mind jumped at the thought that here might be the answer to the billiard advertisement. At nights and holidays he worked away trying to make the cellulose nitrate of the collodion into something that could be used as a billiard ball, and after many months of failure he hit on the idea of mixing camphor with the cellulose nitrate. Here was something that could be molded into a definite shape, that was tough, elastic, and cheaper than ivory. A number of sets of billiard balls were made and were tried out, but with not very satisfactory results. One Colorado saloon-keeper sent his set back with the comment that when his patrons had been playing with them, a cigar had happened to touch one of the balls, and when the smoke had cleared away, every man in the room had his gun out. What was worse, the balls warped a little, giving very unusual effects. This new product, called Celluloid, wasn't the sought-for substitute for real ivory in billiard balls, but it is cheerful to note that Hyatt's new plastic was useful in many other ways, and the Celluloid Corporation soon was a booming affair.

No other real advance was made in the discovery of plastics until 1909, when L. H. Baekeland applied for a patent on a process of letting phenol or carbolic acid react with formaldehyde to form a dark infusible amber-like product which he called Bakelite.

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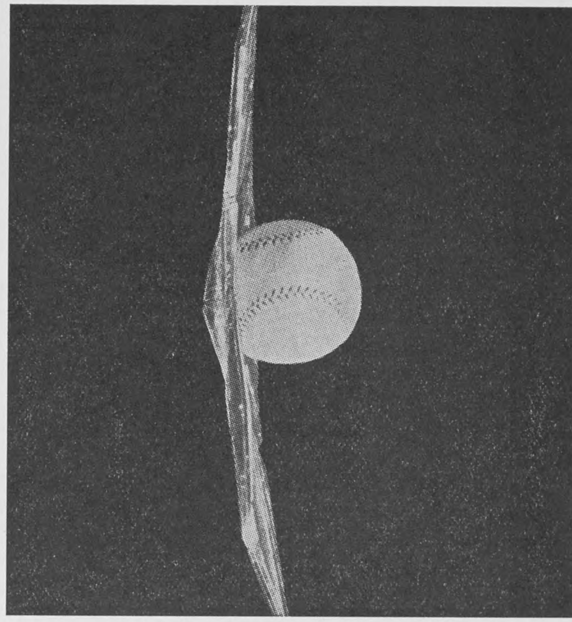


Fig. 1

Shortly afterward, L. V. Redman and J. W. Aylesworth patented Redmanol and Condensite respectively. These products were much the same as Bakelite although made in a slightly different way. Soon the air was full of claims and counter-claims about patent rights, until the three inventors decided that it would be far better for everybody except the lawyers if they joined together, which they did, forming the Bakelite Corporation. Celluloid and Bakelite together had practically all the synthetic plastic field to themselves until 1926, when the basic Bakelite patents ran out; after that there was a very aggressive and stimulating competition and many of the most useful plastics are of recent development.

Before we notice in detail the different types of synthetic plastics, perhaps I should say what a plastic is. One definition says "plastics are substances which behave as solids at stresses smaller than a definite yield value, and as viscous liquids at stresses greater than these." An easier way of thinking of them is as substance which during manufacture can be pushed into almost any desired shape and then keep that shape. In this group are such things as glass, pitch, resins, and natural amber, but I plan to omit further reference to these older materials, discussing instead only the recent synthetic products. These fall into two main groups. Those which are formed into hard non-fusible or non-melting solids by the action of heat and pressure are called thermosetting. Once they have been formed, their shape cannot be changed except by cutting or grinding them or by cracking them. The other type, called thermoplastic products, can be softened by heat and molded into new shapes time after time without becoming permanently set. When they are cool, they behave almost like true solids but they lose this rigidity with an increase in temperature.

All the synthetic plastics belong to that interesting group known to the chemist as compounds of high molecular weight or polymers. These substances are made by building huge molecules up from little ones by making the little ones stick together in units which are repeated hundreds of times, much as individual bricks are stuck together to form a brick wall. We can notice

how this happens in one method of making Bakelite. Phenol (carbolic acid) and formaldehyde join together in presence of an acid catalyst to form a long-chain product of this type.

-P-F-P-F-P-F-P-F-P-F-P-

until there are hundreds of phenol groups (P) joined by hundreds of formaldehyde groups (F). Thus far the product is not "set." It can be melted easily so long as it is in this chain form, and all the thermoplastic products are just very long chains. If some of this product is treated with more formaldehyde in the presence of an alkaline catalyst, it joins up into a net work structure like this:

```
P-F-P-F-P-F-P-F-P-
|   |   |   |   |
F   F   F   F   F
|   |   |   |   |
P-F-P-F-P-F-P-F-P-
|   |   |   |   |
F   F   F   F   F
|   |   |   |   |
P-F-P-F-P-F-P-F-P-
|   |   |   |   |
F   F   F   F   F
|   |   |   |   |
```

This type of product cannot be melted. It is thermosetting. It may be varied in color from very light brown to almost black, and the lighter colored forms may be dyed or mixed with colored pigments to give a great many colors. This type (phenol-formaldehyde) of plastic has a tendency to fade slightly over long periods of time, but for many of its uses this defect is of little importance. It has very good electrical resistance, resists heat, and can be molded under pressure into very intricate forms. One of its common uses is in the manufacture of distributor caps for automobile ignition systems, where the plastic has to fit around and hold tightly the six or eight contact posts of copper. The whole plastic piece is molded in one operation around the copper posts and it comes out in a few seconds a perfect fit with no need for machining to size. Because of its properties and relative cheapness, Bakelite and other similar products are used in making hundreds of common things like telephone receivers and mouthpieces, car parts including gears, table tops, electrical fixtures, radio cabinets, and recently as an experiment a plane whose fuselage and wings are of plastic.

For light colors, another thermosetting plastic has been widely used. This is formed from urea and formaldehyde, the pure product being almost water white. For most purposes it is dyed or mixed with colored powders giving beautifully colored bright products. Under the trade names Beetle and Plaskon, these have been widely used in the manufacture of big electric light shades, for brightly colored radio cabinets, for making dishes and tumblers for camping sets, for

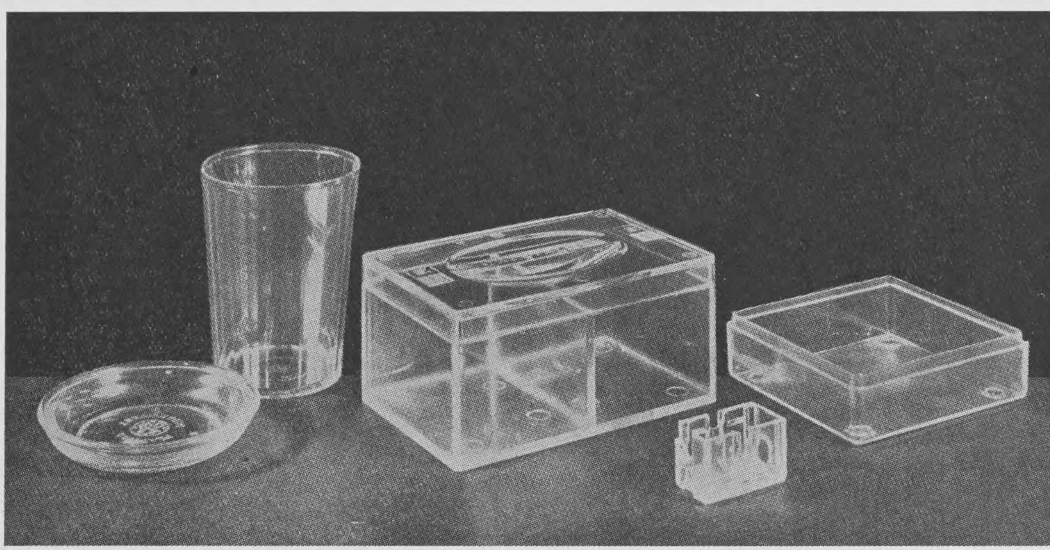


Fig. 2.

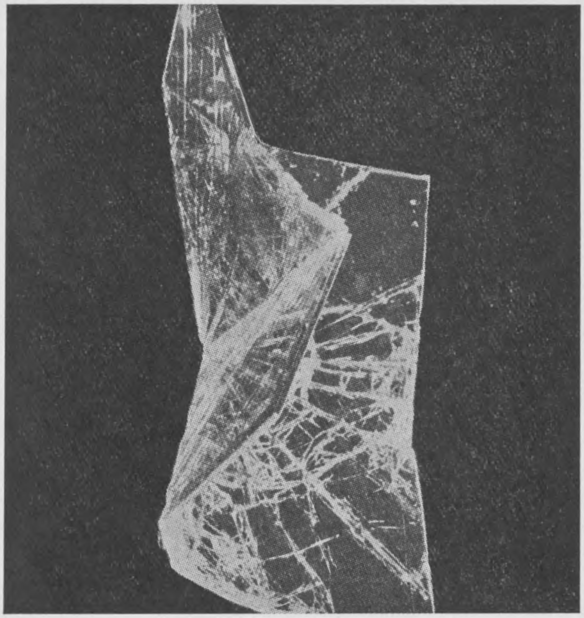


Fig. 3.

making boxes for manicure sets, for making the housings of the newer Toledo scales, and even for teething discs for babies. Yes, they are tough and non-poisonous!

Although these thermosetting materials have been more widely used, the thermoplastic products have been increasing their relative importance in recent years. The first synthetic, Celluloid, is of this type, and it is still being used to the extent of millions of pounds in camera films, professional movie films, tooth brush handles, as the decorative back of mirror and hair-brush sets, and for fountain pens and pencils. Its place has been taken to a large extent by a similar product, cellulose acetate, which is not so readily inflammable. Once Celluloid starts to burn, is continues with great energy, even under water. The acetate will burn if it is held in a fire, but as soon as it is taken out of the blaze, it stops burning. One of its first big uses was in making film for home movie cameras, where the ordinary Celluloid would be too dangerous for common use. X-ray film is also now made from this safer product. It also finds very common use in making decorative lamp shades, bits of personal jewellery, Christmas ornaments, buttons, car fittings, household hardware, brightly colored bedroom telephone sets, transparent boxes, and many other things. An interesting new use for a related product is in the manufacture of several forms of home furniture.

Another thermoplastic type product which has received very wide use is the series of vinyl compounds, polymerized vinyl chloride, vinyl acetate, vinyl butyrate, and other vinyl derivatives. It has been found that mixed vinyl products are more useful than simple compounds, so that trade names identifying different mixtures are generally used. One of these is Koroseal, which has been very widely used for replacing rubber in many things, and we would see a great deal more of it if the whole production was not being used under government priority for emergency needs. Another variety is Vinylite, another Butacite, and there are others. These products can be used for molded products, but generally they are more useful in other ways. One of these is as a flexible coating for copper wire that give a greatly improved insulation, another is as a laminated coating over printed matter to protect it, as a binder and protecting layer for large panels for house and office interiors, as an adhesive for cloth and transparent adhesive tape, and in other ways. One of the most important of these other ways is its use in safety glass as the sandwich material between two thin layers of glass. When safety glass was first made, there was considerable difficulty with two problems, one a gradual darkening of the plastic layer, and the other a failure of the bonding between the plastic and the glass causing the glass to shatter in an accident just as ordinary glass would do. This failure of the plastic to hold the glass firmly was especially bad in this country in winter; but recently the use of a vinyl product in the middle layer has given us safety glass that will hold almost as well at -40° as at 80°. This laminated glass is tougher and more resilient than the former safety glass, but if it does break, it can be rolled up almost like a carpet without the glass coming loose from the middle layer. The bending of the glass due to impact of a baseball is shown in Fig. 1, and the rolling capacity is shown in Fig. 3. A new type of synthetic rattan-like furniture, such as may be seen on newly-built street cars and trains has been made from vinyl products and many of the best industrial filter-cloths are made from the com-

pounds also. Such a filter cloth is highly resistant to the action of dilute acids and alkalies, and also other chemicals, but up to the present time it has not been used much for ordinary textiles because its softening point is so low that pressing irons at ordinary ironing temperatures would be apt to injure it. The research department of the Union Carbide and Carbon Corporation has been spending a great deal of time trying to get a higher melting product without sacrificing the other valuable properties. If it succeeds, there will be a new textile on the market which, like Nylon, will be capable of replacing real silk.

Polystyrene is one of the newest thermoplastic synthetics. It is normally a hard water-white solid, but it is occasionally colored by the use of dyes. Its special value is that it is an excellent insulator and is resistant to the action of acids, alkalies, alcohol, and is unaffected by water. Because of its insulating properties, it is used very widely today in electrical equipment. Its chemical resistance is so good that it is now being used to make the caps for bottles containing the concentrated acids and ammonia, and it is resistant even to hydrofluoric acid, so that it may be used to make bottles for that corrosive fluid. Due to its resistance to alcohol it is used to make decorative cork-covers and pouring spouts for brandy, gin and whiskey bottles. Its resistance to cold embrittlement has resulted in its use as full-view panels in some of the modern electric refrigerators.

I think that perhaps more general interest has been stirred up by the last of the plastics I will mention. Chemically this is either methyl methocrylate or ethyl methacrylate, but the product is better known under the trade names Lusite, Crystalite or Plexiglas. These also are long chain linear polymers and the pure product is beautifully transparent. Before it is molded, it looks like a very fine white sand, but in the molding it comes out as a glass-like solid. (Fig. 2.) In fact it is often spoken of as an organic glass. It is used in some places as a glass, having even greater transparency than ordinary glass and being far less subject to breakage. It is not as hard as glass, and care must be taken not to scratch it or the surface is spoiled. Some of you have, no doubt, observed the nose-pieces on the big T.C.A. planes around the city. These are made of Plexiglas. Most of the bombers and many of the fighter planes have windows or cupolas of this type of material, which is far less subject to damage than ordinary glass. Because of its light transmission and ease of manipulation, it can be made into long curved rods which will carry light from one end right through the rod around the curve to come out at the other end. This makes it of value for certain dental and surgical equipment, where the light is carried right inside the instrument to the site of the treatment. If the rod is roughened on one side part of the light escapes at the roughened region and use is made of this for giving diffused light, as in shades over long tubular lights inside busses. It is also frequently used for edge lighted panels, where the roughened edge gives a soft non-glare illumination in such places as aeroplane instrument panels and decorative signs. By the use of appropriate catalysts, the polymer can be formed without much heat and at atmospheric pressure, and it is finding some use in the preparation of museum specimens. The dried specimen is immersed in some of the partly polymerized fluid and then the rest of the polymerization is carried out giving what seems to be almost a layer of glass over the sample. For delicate things like rare butterflies, this is the only good way of keeping them so that students can examine them thoroughly without danger of damage to the butterfly.

It has not been possible to describe all the types of synthetic plastics which are available, nor could I say much about any of the types that I did mention. It is my hope that I have given you some idea of the nature of this highly important and interesting group of compounds which are making up the new world of plastics.

Sounds We Cannot Hear

by DAVID R. PETRIE, '43 (Hons.)

The production and application of ultrasonics, or high-frequency sound waves, are discussed by an Isbister Scholarship winner.

OBJECTIVELY, sound is a particular form of wave motion taking place in a ponderable matter, whether gaseous, liquid, or solid, due to a disturbance or vibration set up in the body emitting the sound. Subjectively, it is a sensory experience in the brain, conveyed to the latter from the ear. In the subjective sense, sound is much restricted—in the fact that the normal person cannot distinguish as a definite tone, sounds below 16 to 20 vibrations per second, and higher than 25,000 v.p.s. Physically, however, sounds of lower and higher frequencies can be produced, although imperceptible to the human ear. Let us look further into the sounds of higher frequencies than 25,000 v.p.s.—supersonics or ultrasonics, the sounds we cannot hear.

Ultrasonics are most commonly produced by means of the **piezo-Electric Vibrator.** This device arose out of an observation made by J. and P. Curie in 1880, that if a slab cut from certain crystals, notably quartz, be compressed or stretched, the opposite faces become positively and negatively charged; and conversely if the opposite charge is impressed on the faces, the slab changes thickness. The slab, however, has to be cut such that its faces are perpendicular to one of the optical axes of the crystal if the maximum effect is to be obtained. If such a slab be mounted between two plates which are then connected to an alternating current of high frequency, the quartz will vibrate with the same frequency as the current. Much greater intensity is produced if the frequency of the current is adjusted to one of the three natural vibration frequencies of such a plate of quartz. These resonance frequencies can be calculated from an empirical formula devised by A. Hund:

$$n = \frac{2.87 \times 10^5}{t}$$

where t is the thickness of the slab in centimetres. We might note at this point the findings of W. G. Cady, who states that the current falls to half its resonance value if the frequency in a 90,000 cycle circuit varies within 0.05 per cent. Thus, such a device is invaluable in the control of the frequency of broadcasting stations.

Probably the most interesting aspect of this topic is the lethal effects of ultrasonic radiation. If the vibrator is immersed in a bath of oil, which medium will carry the longitudinal waves, and in this bath is placed a tube containing a suspension of the red blood corpuscles of a rabbit in a physiological salt solution, total destruction of the corpuscles will be found after several minutes radiation. The same effect will be noticed if, in place of the blood corpuscles, small unicellular organisms such as protozoa, be suspended in an aqueous medium. This effect has invariably been attributed to tearing stresses which the organisms suffer in the standing wave train. This appears quite plausible in the case of the protozoa, whose sizes are comparable with the wave-length of the vibrations in water, say one or two

millimetres. This means that these large micro-organisms are rent asunder by the passage of the longitudinal waves through them. However it is less convincing in the case of the red blood corpuscles, which are relatively minute. Here the waves cannot pass through them, but they themselves are used as particles by the vibration of which the sound is propagated. This is not in the strictest sense correct, for later it will be seen that these corpuscles are driven by the relatively one-sided heavy bombardment of water molecules from the region of the greatest agitation (antinode) to the region, of least agitation (node) in the wave train. Whether this heavy bombardment is the cause of the destruction, has not been definitely proved. Its effect is considerable, for Ono, working on the disintegration of starches by ultrasonics, explains the mechanism of the reaction partly by the hydrolysis caused by the local heating due to the molecular bombardment. With the particles of starch, no movement towards the nodes was observed.

Experiments conducted to determine the effect of such radiation upon chemical reactions, such as an oxidation-reduction reaction, were performed by Schmitt, Olson and Johnson. Their results seem to indicate that under certain conditions a definite result was noted. In fact they reported that for a solution of Potassium Iodide, in the presence of starch solution, the typical blue coloration was noted to be present after radiation with the ultrasonic waves. This indicated that the radiation alone caused the Iodide ion to be oxidized to Iodine. The exact mechanism of this is not clear, but the workers attributed it to the formation of gas bubbles of the dissolved air and gases in the water for it was not detected with air-free water.

Johnson, working with a knowledge of these facts, set out to find whether this was involved in any way with the destruction of the protozoa and the blood corpuscles. The organisms were irradiated in test tubes, with a connection to an oxygen tank so that external pressure could be applied when desired. Under atmospheric pressure vigorous cavitation of air bubbles was observed and total disintegration of the organisms was noted after thirty seconds of radiation. Cavitation may be explained as follows: as soon as the hydrostatic pressure in a liquid is reduced to the vapour pressure of the liquid, two phases (vapour and liquid) may be formed (formation of a cavity) and then the cavity thus formed is collapsed (collapse of cavity). Lord Rayleigh calculated the pressure developed during the collapse of a spherical cavity. Calculation shows that pressures of 1250 atmospheres may develop at the moment when the cavity collapses to the 1/20 of its original diameter. Intense ultrasonic vibrations may be a cause of this cavitation process. Accordingly a strong mechanical effect may be performed by the cavitation thus produced. A series of experiments were carried out with applied pressures from 10 to 60 lb. per sq. inch, which entirely prevented the effervescence of bubbles of visible size. Up to a critical pressure (varying with the intensity of radiation, but in the neighborhood of 60 lb. per sq. inch), total destruction occurred in the same time as before, but above this pressure the organisms were practically unaffected after two minutes radiation.

Sharp critical pressures were also noted for the radiation of the red blood corpuscles. Above the critical pressure the corpuscles collected at the nodes in pretty patterns, and were not destroyed by several minutes exposure to radiation. Below the critical pressure laking* took place in 30 seconds. Displacement of the dissolved air with CO_2 also prevented haemolysis,* but displacement by pure Hydrogen and Nitrogen did not affect the rate of haemolysis. Both gases, however, were cavitated by radiation under atmospheric pressure.

The corpuscles were then suspended in a medium from which the oxygen, the carbon dioxide and the dissolved air were removed by evacuation. This lack of oxygen causes the corpuscles to lose their red colour, although, as can be seen from the results of the experiment, does not destroy, nor in any way hinder the function of the haemoglobin. Exposure to ultrasonic radiation, under vacuum, produced the "sound patterns" and after about five minutes there was considerable sedimentation. On shaking up the contents of the tube, it was evi-

* Laking, or Haemolysis—destruction of the red blood corpuscles.

dent that no appreciable amount of haemolysis had occurred. Air was then admitted, the red colour returned very quickly, and the test-tube shaken for a minute or two in order to saturate the corpuscles with oxygen. Radiation afresh under atmospheric pressure brought about haemolysis.

Sedimentation takes place fairly rapidly during radiation under conditions such that the corpuscles are not destroyed, and when the radiation is stopped the clusters remaining in the sound patterns sink to the bottom of the tube. Some very pretty experiments can be made. Haemolysis is slow because the radiation density within the liquid is considerably reduced in the narrow tube. Sound patterns quickly appear and then gradually disappear as the haemolysis sets in; sometimes the haemolysis starts at the top on the tube and spreads downwards, and sometimes the reverse is true. In the former case a curious effect is observed; haemolysis will suddenly occur in a narrow region of the tube, the patterns vanishing abruptly as though dissipated by an explosion, perhaps of air bubbles; a few seconds later this is repeated lower down the tube, the air bubbles rising through the liquid disturb the sound pattern. Changes in the oscillation frequency of the quartz crystal between approximately 570 and 1000 kilocycles per second, seem not to influence the results; energy intensity is the important consideration.

A question to be considered in connection with the blood corpuscles is whether the oxygen and carbon dioxide carried by them take part in their destruction, and, again, whether the disintegration of the protozoa is due to the liberation of air bubbles within the cells. It is certainly interesting to consider that necessary parts of the cells are capable of its destruction under the excitation of ultrasonic vibration.

Albeit no experiment has been devised to settle the points unequivocally, there is much evidence against these views. In the first place there is the remarkable parallelism between these lethal phenomena described above, and those of the oxidation of the Iodide ion, mentioned above. In both cases the results of investigation of the critical pressure are strikingly coincidental. With a given intensity of radiation and in water saturated with air at 20° Cent., a critical pressure of 65 pounds per square inch is necessary to inhibit both the oxidation of the Iodide ion and the destruction of micro organisms. Secondly, saturation with the Hydrogen and Nitrogen stopped both reactions. Thirdly, it is doubtful whether any "sound" will be transmitted through the substance of a particle that is free to move about. Energy losses are generally considerable at interfaces and a relatively heavy bombardment by water molecules on one side of the suspended particle will merely drive it towards a node. Hence the sedimentation of blood corpuscles, (and also the rapid settling out of the starch granules from aqueous suspensions) under the influence of ultrasonic radiation. It seems likely that the lethal action is from without rather than from within; external rather than internal.

Passage of the ultrasonic vibrations through re-distilled water causes luminescence, which has been photographed. A brass vessel, filled with about one hundred cubic centimetres of the water, immersed in the oil bath (conveying vibrations of about 500,000 cycles) can be used to illustrate this. In a darkened room, and by the use of a paper tube corresponding in diameter to the vessel itself, there regularly appeared, directly after the commencement of the vibrations, a faint but clearly visible light phenomenon, which is regularly reproducible.

Water that has undergone the above treatment, if it contains air or dissolved acids, is shown to contain hydrogen peroxide. From indications of this process it seems that the production of frictional electricity through the violent mechanical motion at the relatively large boundary surfaces between liquid and the gas bubbles leads to the dissociation of the oxygen molecules, similar to the mechanical way in which ionization is brought about in the case of frictional electricity. The resulting oxygen atoms are then absorbed by the water to produce H_2O_2. This also explains the luminescence explained above, due to the presence of electrical voltage, with the formation of H_2O_2 explained as purely a secondary effect.

This mechanical bombardment mentioned in the theory above, also produces various

other phenomena. Cane sugar is broken down to the mono-saccharides. This is most interesting, as it may furnish a measure of the strength of chemical links by the break-up of compound molecules by these vibrations. Starch is depolymerized as is shown by a fall in the viscosity. In this case the iodine blue of the starch changed to the typical dextrin red, showing it was not an ordinary breakdown. This could lead to an ultrasonic investigation of the highly polymerized substances. The ponderous molecules of the proteins are broken into definite fragments by such a treatment. The protein "Haemocyanin" from Helix Pomatia, of molecular weight 6,740,000 was irradiated with waves of a frequency 250,000 cycles per second. When subjected to analysis of weight by the ultra-centrifuge, uniform fragments one-half and one-eighth of the molecule were found. Similar results were noted with the amino acids.

These vibrations are being used more extensively in the preparation of certain colloids unavailable by the common means. The dispersion is effected by the great strain set up at the interface, due to which particles of the colloidal size, as well as larger size are torn from the one and scattered throughout the other. Thus has been obtained, as an example, the unusual colloidal dispersion of Mercury in water. Further investigation by the same authors, reveal that latent images are produced on photographic plates by the same agency. This again is explained as due to the energy of bombardment. The effects of ultrasonics of 723,000 cycles per second upon Ehrlich's Carcinoma were investigated. However the results were negative, no detectable result being produced.

Ultrasonics, especially of the lower ranges, are not confined to the laboratory, as it would seem upon first glance. Investigation reveals that many of the common animals, such as cats, dogs, and rabbits possess the ability to discern sounds beyond the human range. In fact one manufacturer in the States has made use of this fact by making a whistle of supersonic range. Use of this to call home the family pet greatly improves relations with the neighbors, rather than the use of prolonged and annoying whistling. In nature the most practical use of these sounds is probably made by the bat. It is a well-known fact that this mammal has unusual skill in "blind flying." Imprisoned in a darkened room, crossed and recrossed with blackened piano wires, this bird suffers no difficulty in flight, never striking the obstacles. This is now being explained by assuming that the bat is continually emitting supersonic sounds, and detects obstacles by sharp echoes reflected by them.

Langevin devised a supersonic oscillator, with a frequency of 50,000 cycles, which could be used under water. Since the velocity of sound in sea water is 1435 metres per second, with a frequency of 35,000 cycles the wave length of these vibrations is 4.1 cms. These short wave lengths give sharp echoes from the bottom. Thus by measuring the time it takes for the "sound" to return to the ship, the depth may be calculated. This same quartz oscillator may also be used for submarine signalling between vessels, although miles apart. The receiver identical with the transmitter, must be closely tuned in order to respond to the impressed vibrations. Due to this, an enemy vessel could not inadvertently intercept the signals. The received signal is converted to audible tones by the same devices as are used in radio reception. Similar signalling through the air is possible, although the range is limited by the absorption of the sound by the air, especially if rich in carbon dioxide.

The study of ultrasonic vibrations constitutes a new and fertile field of investigation for the Physical Chemist interested in their effects on macro-molecules, the Physicist interested in their production and application, and the Bio-Physicist interested in their effects on living organisms. Much new and interesting material will be published by these three types of scientists in the near future.

SURFACES

A graphic account of the physical aspects of surface phenomena

by J. HAMILTON B.Sc. (Hons.) (Man.) M.A. (Tor.) '38

IT IS only within the past two decades that the nature of surface has come into its own proper importance in physics and chemistry. Viewed historically the development of these sciences has followed along lines laid down by broad theoretical principles. In these principles there was, as a rule, little to direct attention to the surfaces bounding bulk masses. Chemistry was interested in mass reactions and in these the surface played no obvious role. Physics largely ignored the experimental study of the ponderable masses of non-atomic mechanics and left this field to the engineer. In doing so, it neglected surface tension—the one physical quantity which was thought to represent the character of the surface. The attention of physics was taken up by the intense exploration of the main stream, tributaries and head waters of the electromagnetic system.

This picture has now been changed. The literature of physical, industrial and colloidal chemistry now abounds with discussions on the nature of surface.

The new emphasis upon surface is due to its importance as a seat of chemical activity. This chemical activity is of a type which is of tremendous practical importance. That most academic of inventions, the radio tube, depends for its efficiency upon the nature of its emissive surface; the flotation of minerals is entirely a surface phenomenon; much of the electrolytic decay of metals is traceable to a surface cause and living cells literally assimilate, grow and divide by means of surface mechanisms.

As a branch of experimental science, the surface is still a very young subject and it is our purpose here to relate a little of its growth from a branch of hydrostatics to its present very promising position.

Dr. Irving Langmuir, undoubtedly one of the greatest chemists of our time, has been very largely responsible for the present knowledge of surface but prior to his initial achievements in 1917 certain ill-conceived notions had to be destroyed and newer, more correct ideas instituted. These lay in the concept of surface tension and are due primarily to observations on oil films made by Fraulein Pockles and Lord Raleigh.

The old classical view had held that molecules lying in a liquid surface had the ability to join forces with their neighbors in the surface and create a pull parallel to the surface. These forces were presumed to form a contractile skin, composed solely of molecules of the liquid, and this mechanism was used to explain the fact that surfaces tend to draw inwards; we say that surface area tends to a minimum. The most familiar and striking example of this is the spherical shape of a rain drop—a spherical surface being the least surface area for the volume enclosed. This contractile skin idea is not present in the modern view which asserts that it is cohesion between surface molecules and those below which tends to pull the surface inwards. The end result is the same but the mechanism involved is quite different.

In the modern view, too, surface tension is not a force (as tension applies) but is **energy** which is a physical concept of quite different dimensions. How the error was made originally is quite easily seen if we accept the theory of the surface "skin" and do not enquire further. Since the skin is pulling parallel to the surface, they argued, it must have a force, and this force we shall

call surface tension. Custom has preserved the usage of the term but it would be much better if we spoke of surface energy instead. The newer concept is really much simpler than the old as it does not leave the mind to carry the idea of an imaginary surface skin. Molecules within the liquid share their energy fields with their neighbors above, below, and to each side of them; those in the surface have no molecules above them and there is therefore an amount of free or unshared energy above. This free energy, in the modern view, may be equated to a **purely mathematical fiction** called surface tension.

To further illustrate the differences between these two views of surface tension the following quotation from Osborne Reynolds is given. In describing the spreading of oil on a dust-covered surface he writes: "The result is to give the impression that the dust is being driven back by the oil, as if the oil were spreading by some inherent force but, as a matter of fact, the oil is being drawn forward by the contraction of the dust-covered surface of pure water."

N. K. Adam, from whose excellent work **The Physics and Chemistry of Surfaces,** the excerpt is taken, remarks, "It is interesting to note how Reynolds' first impression, based on his own observation of the mechanism of spreading was that it was due to an expansive force. At that time, however, the predominance of the theory that liquids have skins was so complete, that he felt obliged to abandon his own correct impression and to wonder why this supposed skin was not apparent as a contraction at some distance in advance of the spreading oil."

Here then is the crux of the matter. The two views will, in a limited sense, lead to identical mathematical representations. But the former directs the attention of the observer away from the area covered by the oil to the pure water around it for it is here that the supposed mechanism responsible for the spreading is located. The latter directs attention to the oil-water relations.

If we return for a moment to the idea that surface tension is free energy we can see why this should be so. Both the water and the oil lens have unbound energy on their surface. The reason for the spreading is simply the matching up of these free energy fields. The rule is that nature prefers to have stabilized or bound conditions and spreading is simply a physical process contingent upon the matching up of the free energy fields of the water and oil in such a way that a greater amount of energy is bound than was previously the case.

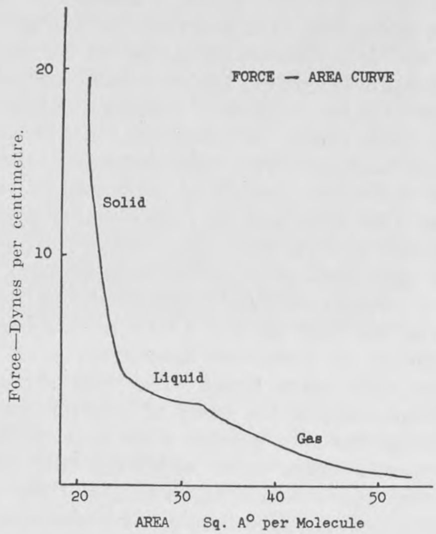
This statement may be qualified. Many substances have an affinity for water and still they do not spread. For example, metallic solids are wet by water. The qualifying rule states that the cohesive force between the molecules of the substance to be spread must be less than the adhesive force between the water and the molecules.

From this rule it may very correctly be inferred that the nature of the molecules to be spread has a great deal to do with the phenomenon of spreading. The question might then be asked, "If the substance to be spread should be wet by water why should oils be chosen as an example?" These, at first glance, abhor water completely. The hyrocarbon compounds seem to have the least liking for water of many common chemicals. As a matter of fact, this is not true. The glance, abhor water completely. The hydrocarbons have a very definite affinity for water. But one part of these molecules—the paraffin chain—will not wet, and by reason of this and the "simple complexity" of their structure, the hydrocarbon acids, salts and alcohols played a major role in Langmuir's experiments of 1917.

The structure of hydrocarbon molecules is in two parts. The first of these is a long carbon chain, fringed along the sides with hydrogen atoms. Our knowledge of this portion indicates that it is very stable chemically: it gives hydrocarbon compounds their greasy characteristics, and it is repellant to water.

The second part of the molecule lies at the end of this chain. For each member of homologous series the length of the chain increases but the physical structure and chemical properties of this end group remain the same. For the acid series the end group is -COOH, for alcohols it is -CH_2OH and so on. These groups are chemically active, have a high free energy and are soluble in water.

Now we can easily see that the spreading of the hydrocarbon is due to these end groups for it is this part which has an affinity for the water. With the hydrocarbon chain repellant to water an interesting situation results. The active end tries to pull the



molecule into solution, the chain tries to keep it out. Experiment has shown that the tendency of the acid group, for example, to dissolve is so strong that it takes a chain of some fourteen carbons to prevent a solution of acid and water.

One other result of this lack of symmetry in the hydrocarbon is that there is a very high degree of orientation in the surface film. The water attracting groups are oriented towards the water so that the interface may be regarded as a surface solution of the active group in water.

The molecules of these films may thus be regarded as floating objects and it is obvious that if we bring these objects into contact they will resist lateral compression. This resistance is called surface pressure. Like the old idea of surface tension, it is a force acting parallel to the surface but unlike the tension it acts **outwards** from the film molecules, not **inwards** like the contractile skin. This surface pressure is analagous, in two dimensions, to gas pressure in three dimensions.

Surface pressure, like gas pressure, can be measured and it gives us a great deal of information about film structure. Before giving a very brief description of film pressures, t would perhaps help to describe how it is measured. The film is placed on the water surface which is held in a rectangular tray. The tray is brimful so that the water heaps well up over the level of the edges. The film is trapped between two barriers each of which completely cuts the surface into two parts so that a surface molecule on one side may not move to the other side. One barrier is movable, the other is a lightly fixed float. The area of surface may be regulated by the movable barrier so that, in doing so, any pressure changes are felt by the float-barrier. To the float is attached a measuring device—usually a torsion wire or a balance, and by this means, the pressure against the float is measured.

Now let us suppose that so few film molecules are floating on the surface that they are widely separated, single molecules. The film pressure is barely noticeable (less than one dyne per centimetre of float). Now in successive steps the area offered to the film molecules is lessened by the moveable barrier. The pressure rises slowly and smoothly. (See figure.) X-ray observations of these films of low surface concentration show that they are very thin—about 4 Angstrom Units. It is thought that the hydrocarbon chains are not standing erect but are lying at an angle so that they are quite close to the water. Due to the kinetic motion of the film molecules, these chains are lashing about, striking against one another and the floating barrier. This creates the pressure which is observed. Films in this state are referred to as gaseous. They obey the equation

$$PA = RT$$

which is similar to the well-known gas law equation with the area A substituted for V, the volume.

Further limitation of the area changes the character of the film to what is known as the liquid state. As the film area is decreased the molecules are forced closer together. Molecules strike one another more frequently. Due to a lateral adhesion between the paraffin chains the molecules become linked together to form islands. X-ray data shows that the film thickness is increased many times over that which it was during the gaseous stage. This indicates that these islands of molecules have the chains orientated more nearly perpendicular to the surface.

The solid state of the film is finally reached. The islands of molecules are brought into contact and rearrange themselves until the surface is covered with a uniform,

Footnote: *Angstrom unite—.003937 millionths of an inch.

oriented, monomolecular film. The solid nature of the surface may easily be demonstrated by sprinkling a little talc on the surface. Gentle blowing on one portion will create a movement of all parts of the film because of the rigidity.

The area at which the film becomes a solid is quite significant and is marked by a definite change in the shape of the force-area curve. For, from Avogadro's number we can calculate the total number of molecules which were originally placed on the surface. (The procedure is to use a known volume of a known dilute solution of the hydrocarbon compound in benzene. On being placed on the surface the benzene evaporates.) Therefore, the area at which these molecules touch, found from the force-area curve, divided by the number of molecules, must give the area of cross section of each molecule. The fact that this area is found to be the same for each member of a homologous series is a part of the experimental evidence in favor of the previous remark that the active groups are oriented towards the water. For acids, this area is 20.5 square Angstrom units for alcohol, 21.6 square Angerom units.

The hydrocarbons are not the only chemical compounds which form surface films. Benzene derivatives, mambers of the amino acid compounds and proteins will form films and from these a great deal of valuable information regarding the structure and properties of these substances has been secured.

The importance of films can hardly be over-estimated. The hydrocarbons films which have been described were among the earlier examples and are therefore of some historical importance. As such they have had a good deal to do with the development of the techniques and theories of surface films as has been indicated. From this basis the theory of films has broadened until it touches upon many fields. The laws of mass action are used in the study of reaction rates of the active film groups with ions in the substrate or liquid upon which the film lies. Film structure touches upon colloidal theory for it is now thought that many colloids are these two dimensional layers folded so that they become space enclosing.

It is not necessary to cite further examples of surface absorption. The surface, as an object of experimental investigation, will receive an increasing amount of attention in the future. Much is now known, a far greater amount remains to be discovered. Of this subject it can be truly said that as yet, the surface is barely scratched.

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Chemical Life Savers

Israel Herstein '44, gives an account of the Sulphanilamide compound.

THE alchemist of the Middle Ages constantly sought the key to three great problems: that of finding the universal solvent which would dissolve everything, that of successfully transmuting base metals into noble metals, and that of discovering the elixir of life—the elixir which would give eternal youth and provide a remedy for every ailment and disease. Although in his researches the alchemist did discover many new facts and substances, he failed to solve the three problems mentioned. It took his 20th century confrères to materialize a large portion of his fond dream.

Thus, of the three major goals, each one has been very nearly reached. The universal solvent is indeed universal. It is water which dissolves everything to some extent. The physicist, by bombardment of the atomic nucleus, has transmuted one metal into another. And now the chemist has stepped onto the threshold of the answer to the third problem, that of finding the much desired elixir; and strangely enough, the elixir is not an elixir at all; it is a powder, a white powder—Sulphanilamide.

Let us trace the short but eventful history of this miracle powder, whose story is as dramatic as any movie thriller. It was not until the year 1908, that the chemist Gelmo synthesized a compound, *p*-amino benzene sulfonamide. In the following year Horlein, Dressel and Kothe, chemists for the I.G. Farbenindustrie, in Germany, prepared various azo dyes, for commercial textile purposes, from *p*-amino benzene sulfonamide. In the following few years, little was done with these dyes. However, in 1914 Eisenberg noted that one of these dyes, Chrysoidine (2, 4 diamino azobenzene) was bactericidal *in vitro* (outside living body). Heidleberg and Jacobs developed a number of azo dyes which they described as being highly bactericidal *in vitro*. One of these dyes was *p*-amino benzene sulfonamide hydrocupreine. In the years between 1917-30, little was done with these dyes. But in 1930, Mietzch synthesized atebrin which he found to be quite effective in the control of experimental streptococcal infections. In 1932, Mietzch, in collaboration with Klarer, patented Prontosil as well as a few other sulfonamide-containing azo dyes. At a meeting of dermatologists at Dusseldorf in 1933, a German doctor, Dr. Foerster, brought news of a mysterious drug, known as Steptozon which had saved the life of a child, blood-poisoned by staphylococcus. The next year, the drug was renamed Prontosil in the treatment of erythema (abnormal redness of skin due to capillary congestion). Puschel and Gmelin reported the successful use of Prontosil in the treatment of erysipelas (inflammation of skin, accompanied by fever) and streptococcal empyema. This proved beyond doubt that Prontosil could be used in diseases caused by hemolytic streptococci. But thus far no experimental data relating to Prontosil had been reported. In 1935, however, Herhard Domagk, working in the I.G. Farbenintustrie in Eberfeld, Germany, announced a remarkable experiment he had performed; he had injected mice with deadly streptococcus and then had given them the reddish dye, Prontosil. Not a single mouse died! Everyone was skeptical. It was too perfect! It could not be! But it was.

Now from the Paris Institute, M. and Mme. Tréfouel, M. Nitti, and M. Bovet suggested that all these azo dyes broke down, in the

living tissues, into sulphanilamide (*p*-amino benzene sulphonamide). They isolated this compound the same which Gelmo had synthesized in 1908, from Prontosil.

Horlein spoke before the Royal Society of Medicine in London on October 3, 1935, about the wonder drug which cured not only streptococcus rheumatism, erysipelas, puerperal fever, but also meningitis and Hodgkin's disease. Leonard Colebrooke repeated Domagk's work and confirmed it. He tried Prontosil on patients sick with puerperal fever at Queen Charlotte's Hospital in London. The results were amazing! The percentage of recoveries was unbelievable.

Long, a young American doctor, heard about this drug while he was in London. He was skeptical, however. But by chance, during a chat with Ronald Hare, he was told by Hare, a microbiologist, how he had been saved from death due to streptococcus, by Prontosil. Long became a confirmed enthusiast of this drug. He returned in 1936 to the United States with samples of Prontosil, Neoprontosil and Sulphanilamide. He and Dr. Eleanor Bliss, began working at John Hopkin's University, with mice. They divided a batch of mice in two, and both groups were strongly injected with streptococcus, but only one of the groups was given Prontosil. According to theory, all the mice should have died. But, of those given Prontosil, 90% lived. It was at that time that a friend of Long's, Dr. Schwenker came to him and told of a young eight-year-old girl seriously ill with erysipelas, temperature 106°. Could Long do something for her? Long suggested using Prontosil. Within eight hours the redness of the skin had disappeared, and in 36 hours, all fever had subsided. Long now began concentrating on the cheaper Sulphanilamide. In November of 1936, he reported that he had treated 70 seriously ill people with Sulphanilamide, and that of these, all but four recovered, and of these four, three were near death when they came under Long's care. In December, Long had a very sick patient brought to him. It was a six-year-old girl, dying from meningitis, a disease which killed 90% of its victims. On December 7th, Long began treating her with Sulphanilamide, and on December 25th she went home, fully recovered, saved from the grave.

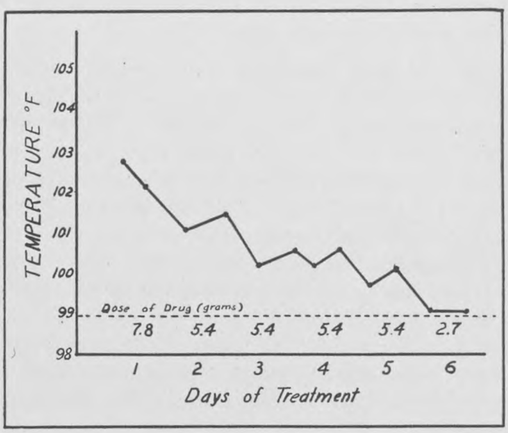
Thus we have followed through the course of discovery of Sulphanilamide and have seen something of the development of its use. But Sulphanilamide is but one of the ever increasing family of Sulpha-drugs. It was discovered that Sulphanilamide, was practically useless for pneumococcal infections, and so researchers in 1938, found a sulpha-drug that was effective in this field —Sulphapyridine. Even back in 1936, Goissedet had prepared Septazine, a benzyl sulphanilamide. To this list was added Sulphathiazole, particularly effective in staphylococcal infections. A more recent drug is sulphanyl guanidine which is used for Bacillary Dysentry and Cholera. Promin, although not yet established firmly, has been found to be effective in Tubercolosis therapy. Each drug has its field of attack, and is best only in this field. But many are toxic, and so their use is limited.

The question of how the sulpha-drugs act has been greatly discussed and argued over. Many theories have been devised and many experiments performed to back up these theories.

All the theories, however, can be arranged into two sets: one group which suggests that the drugs act chemically on the bacteria, and another type which propounds that the drugs have an effect which tends to stimulate the natural defences of the body.

Many observers have noted that Sulphanilamide inhibited the growth of streptococci in cultures. Calebrooke and Kenny even went farther, reporting that the drug was bactericidal *in vitro*. Thus a similar effect could be expected *in vivo*.

Levaditi and Vaisman believed that the



drug acted by interfering with capsulation. "It is quite possible that the azo derivatives *might* act therapeutically by hindering encapsulation, by facilitating phagocytosis, and by helping the host to defend itself." They published pictures showing the absence of capsules in certain streptococci after treatment with Prontosil. As a matter of fact, Sulphapyridine has also been shown to attack the capsule of pneumococus in a destructive manner. After the capsule has been destroyed, the leucocytes can advantageously attack the micro-organisms. Some medical men hold that the sulpha-drugs act by neutralizing the toxins of the microbes. Bosse observed a loss of hemolysin* production by streptococci cultivated in the presence of Prontosil. The theory accepted by most medical men, however, is that since Sulphanilamide can dissolve in the blood quite readily, it can reach a high enough concentration to inhibit the growth and propagation of the bacteria, so that the healthy tissue, antibody and white blood cells can take care of the "bugs." Also, since the blood stream circulates throughout the entire body, the germs are attacked on all fronts.

The action of the drugs by stimulation of the body defences has also been explained. Some medical quarters have advanced a theory that the compounds promote antibody formation, but this theory has been received only to a very small extent. A great number of investigators have considered that the sulpha-drugs act by stimulating phagocytosis.

Thus, many theories have been suggested. The true answer is probably a coupling of a few of these. Only the future can bring an answer.

Let us now consider each drug, the kinds of infections in the treatment of which each one is effective, and its special attributes and shortcomings, in its own field.

Sulphanilamide has found very many uses in the medical world. It can be so widely used in chemotherapy because it is easily received by the body and is excreted without difficulty. It can reach a fairly high concentration in the blood stream and so can combat disease effectively. It has its faults in giving rise to rashes, fever, vomiting, dizziness, nervous twitchings, and sometimes even to more serious effects, such as anemia and cyanosis.

The diseases in which it finds its greatest use can be divided into four groups: Hemolytic Streptococcal infections, meningococcal infections, gonococcal infections, urinary tract infections. The following diseases have been treated, very successfully with Sulphanilamide: Ludwig's Angina, scarlet fever, streptococcal meningitis, erysipelas, cellulitis, empyema, peritonitis, puerperal fever.

Meningococcal meningitis, caused by meningococcus, has been put well under control by Sulphanilamide. Of 271 patients treated with sulphanilamide only 29 died. That is, the fatality rate was only 10.7 per cent. Previously, this disease had a death rate of about 70 per cent.

In the treatment of uirnary tract infection, Sulphanilamide has still other advantages. It is cheap and can be administered to infants and children without difficulty.

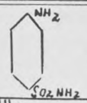
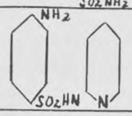
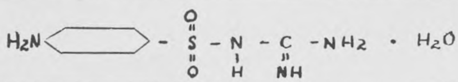
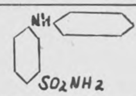
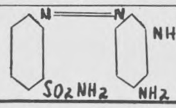
The miscellaneous infections treated with Sulphanilamide includes in its number straphylococcal infection, gas gangrene and trachoma (inflamed condition of the eyes).

Sulphanilamide is also used to some extent in surgery. Thus in an appendectomy, when peritonitis has set in, the wound is swabbed with Sulphanilamide solution and the powdered form is left in the wound to prevent infection. This has decreased the death rate in "burst appendix" to a negligible figure.

The discovery of Sulphapyridine in 1938 electrified the medical world. This drug has found its greatest application in the treatment of diseases due to pneumococcus. It has also found its use in the therapy of some caused by streptococcus, meningococcus, bacillus coli and others. In all these infections, since it is only one-quarter as toxic as Sulphanilamide, it has found great application.

Thus, of the pneumococcal group, lobar pneumonia and pneumococcal meningitis have both been treated with great success with Sulphapyridine. In lobar pneumonia, the case fatality among patients was about twenty-five per cent. Now it has been cut down to about 4%. The drug cuts down the temperature in about three days, and recovery is prompt. Pneumococcal meningitis therapy with Sulphapyridine is but in the experimental stage. In the streptococcal and meningococcal infections, the drug is as ef-

*Hemolysin—Substance secreted by certain streptococci. It destroys red blood corpuscles.

MEDICAL NAME	CHEMICAL FORMULA
Sulphanilamide	 p-amino benzene sulphonamide
Sulphapyridine	 2-sulphanilamidopyridine
Sulphaguanidine	
Septazine	 benzyl sulphanilamide
Prontosil	 4'-sulphonamido-2,4-diaminoazobenzene

fective as Sulphanilamide. The former, however, has quite a few disadvantages. To begin with, it is not easily absorbed by the body; and then too, the phenomena of vomiting, dizziness, and nervous twitching are more marked in cases treated with Sulphapyridine, than those treated with Sulphanilamide.

Sulphathiazole, one of the more recent sulpha-drugs, has already set its mark as a useful agent in the treatment of staphylococcal infections. It also has some value in pneumococcal infections, but is usually replaced by Sulphapyridine. It finds its best place in cases where Sulphapyridine is not tolerated by the body. As to its toxicity, Sulphathiazole is less toxic than the other drugs of this family.

Septazine, still another sulpha-drug, has been introduced to a limited extent only, into the United States, but has found great use on the continent. It is one of the first sulphonamide derivatives to be discovered, (being reported by Goissedet in 1936). Its very low toxicity, coupled with a high degree of antistreptoccoccic activity, find it a definite place in the field of sulphonamide chemotherapy. It is particularly useful in conditions due to hemolytic streptococcus. A soluble septazine, soluseptazine, has also been prepared and used.

Sulphaguanidine, the guanidine analogue of sulphapyridine, is a sulphonamide distinguished by its high solubility in water, yet low degree of absorption by the stomach tissues. Thus, it tends to remain in the colon and exerts its bacteriostatic influence there. Accordingly it is of great use in bacillary dysentary, cholera, and as a preoperative and post-operative measure in surgery of the colon. It may cause a tide of crystals in the urine, and these may cause injury to the sensitive excretory organs if the drug is not administered correctly.

The last drug, little of which is known, is Promin. It is believed to be effective in the treatment of tuberculosis.

The sulpha-drugs have had their trying days. As a proof, in 1937 at least 76 persons died in the United States as the result of poisoning from a solution of Sulphanilamide in diethylene glycol. Due to its high toxicity, Sulphanilamide itself is rarely used today. The more recently discovered sulpha-drugs, such as Sulphapyridine, Sulphathiazole, and Septazine, are of lower toxicity, and so are put to greater use.

This field is not as yet a closed one. Research workers are experimenting every day in search of new and better drugs. The toxicity of all the sulphonamide derivatives is one factor which hinders their use to a great extent. But their advantages by far outweigh their disadvantages. They are truly the modern elixir of life.

Bibilography: Sulphanilamide—Long and Bliss.
The Fight for Life—Paul de Kruif. Modern Miracles—Ratcliff.

The Fourth Dimension

by HART FAINTUCH '42

AS AN introductory remark to this article, your writer wishes to state that this is only an elementary consideration of the fourth dimension. The article is such for two reasons:

1. If the article were at all involved, you wouldn't understand it.
2. Neither would your writer.

We must all agree that at the beginning of every new subject, an atmosphere—a mood—a point of view—must be created. When you go to a seance, for example, the room is darkened, and eerie lights are used. The purpose of all these strange effects is to create a mood. Similarly, before you go skating, swimming, or to the theatre you must be in a certain mood. Here, too, then, in order for you to accept certain facts you must be in a certain frame of mind: Be ready to use your imagination, and try to visualize almost the impossible. Don't condemn anything that is said because you yourself have not actually seen the said thing happen.

If you are ready to comply with the regulations, we may proceed with our discussion of the fourth dimension.

The first consideration, of course, is the source of the concept of our subject. Where did the idea originate? The idea originated primarily as a mathematical concept. In mathematics we encounter certain equations. These equations each have a spatial equivalent. We have equations with one, two, three and more unknowns. The spatial equivalent for an equation with one unknown is in the first dimension, for an equation with two unknowns—the second dimension, with three unknowns—the third dimension, and with four unknowns . . . (are we snagged!) Thus an equation like

$x = p$ represents a point in 1 space,
$ax + by + c = o$ rep. a line in 2 space.
$ax + by + cz = o$ rep. a plane in 3 space,
$ax + by + cz + dw + e = o$.

(where x, y and z are the unknowns). Our subject leads us to believe that an equation like $ax + by + cz + dw + e = o$ is the equation of a 3-space in 4-space. Similarly, x represents a point, x^2 = a square, x^3 = a cube and x^4 = a cuboid (or 4 -space).

We must realize that the mathematician created the fourth dimensional concept for convenience in manipulation, and not because he wished to visualize what the fourth dimension is. The first mathematician who tried to take 29 from 27, say, could not possibly visualize what (—2) was. Imagine having (—2) of anything! The first person to run across $\sqrt[3]{-1}$ couldn't visualize what it meant either, so he called it an imaginary number and represented it by "i". So, too, the mathematician created the fourth dimensional idea for convenience.

Unfortunately, spiritualists and magicians saw in this new idea an opportunity to create for themselves a new world of mystery to others. These people created new words and new ideas, and now we have the fourth dimension.

If a point moves a distance "d" in any direction, it creates a line. If a line moves a distance "d" in any direction outside itself it creates a plane. If a plane moves a distance "d" in a direction outside itself, it creates a three-dimensional space. If a three-dimensional object moves a distance "d" in any direction outside itself, it creates a four-dimensional space. Any space moving outside itself creates higher space. If all the above movements are perpendicular ones, we get generated a line, a square, a cube, and a tesseract or cuboid, respectively.

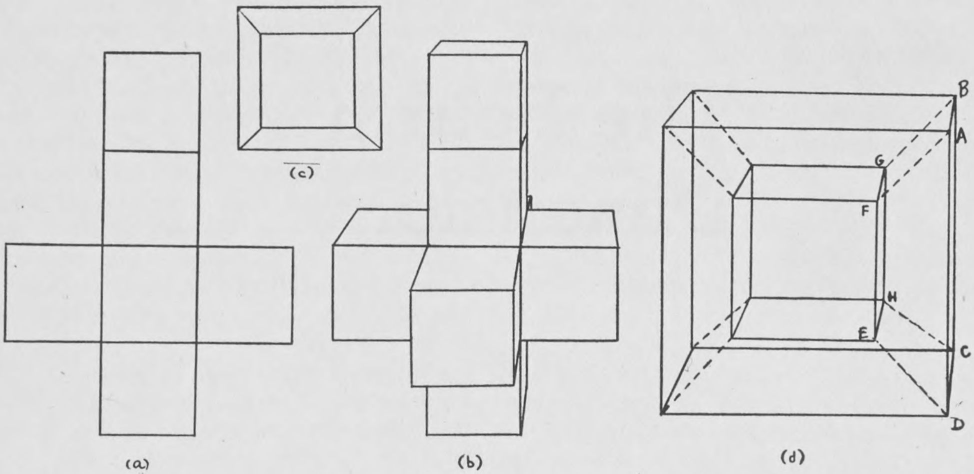


Fig. (1)

Using your imagination, then, think of a one-dimensional world. People living in this world have no height or width. Their sole dimension is length. Their motion is restricted to a line. (For convenience let us call it a straight line.) They cannot imagine such a thing as the second dimension. To them it does not exist. Two lines drawn across the line of motion of these 1-space inhabitants would be sufficient to imprison them within the confined space. These people could not go over or around the confining lines for they are ignorant of such motions. Similarly, imagine a two-dimensional world, the inhabitants of which know only of length and width, but not height. A triangle or square drawn around these people would imprison them. Criminals in the third dimension know, of course, that four walls, one floor and one roof are sufficient to imprison them.

Any person inhabiting higher space can penetrate lower space. Thus a two-dimensional man could free a one-dimensional man by taking the latter through the second dimension (width) around the confining line. A three-dimensional man could free both the one-dimensional and two-dimensional men by lifting them both through the third dimension (height), and placing them on the other side of the confining lines. Similarly, a four-dimensional man could free the three-dimensional prisoner by taking him momentarily through the fourth dimension and placing him outside the prison. (Unfortunately, few prisoners know fourth-dimensional men and must rely on three-dimensional pardons.)

It is impossible for us to imagine what a fourth-dimensional object would look like **in the fourth dimension,** but we can by analogy try to imagine what it would look like in the **third** dimension. A line is made up of an infinity of points. If we had a square made of wire, and if we cut it at one of its corners, and unfolded the sides, we would get a straight line. If we cut a hollow cube (imagine it to be made of cardboard) along its edges, we would get a figure like Figure (1) (a). Similarly, if we cut a tesseract or cuboid (a fourth-dimensional figure) in the proper places, we would get, by analogy, a figure like Figure (1) (b). (Notice that upon each square of (1) (a) a cube has been drawn giving Figure (1) (b)).

If we stop to consider the boundaries of these various figures we find the following:

	Points	Lines	Squares	Cubes
1 dimensional unit	2	1	0	0
2 dimensional unit	4	4	1	0
3 dimensional unit	8	12	6	1
4 dimensional unit	16	32	24	8

We may conceive of the fourth dimensional cuboid in the third dimension in another way:

Suppose we have a glass cube. Closing one eye, we can look into its depths. The cube will appear as in figure (1) (c). Notice: that one square is within the other; that the corners are connected by lines; that the figure is really a two dimensional figure—

that is we have projected a three dimensional object into a two dimensional one. By analogy a cuboid would look like figure (1) (d). Notice that in the figure one cube is drawn inside the other, and that corresponding corners are connected by lines. Here too we may determine the boundary points, lines squares and cubes. (Consider a solid body like A B C D E F G H as a cube. Remember that it is a projection from the fourth dimension, and does not necessarily have to look a cube to be one.)

Leaving our discussion of boundaries, consider figure (2) (a). Here we have two squares identical in every respect, except that the squares are so lettered that one is a mirror image of the other. Try as we might, we can find no way of twisting square No. 2 **in the plane of the paper** so that it will exactly coincide letter for letter with square No. 1. It is a simple matter, however, to cut one square out of the paper, turn it over **through the third dimension** and lay it down so that it coincides exactly with square No. 1. Now look at figure (2) (b). Try as we might, (even in the third dimension) we cannot get a cube to coincide exactly with its mirror image. All a fourth dimensional person would have to do to attain the desired effect, however, would be to lift cube (2) into the fourth dimension, twist it over while there, and set it down into the third dimension as its mirror image.

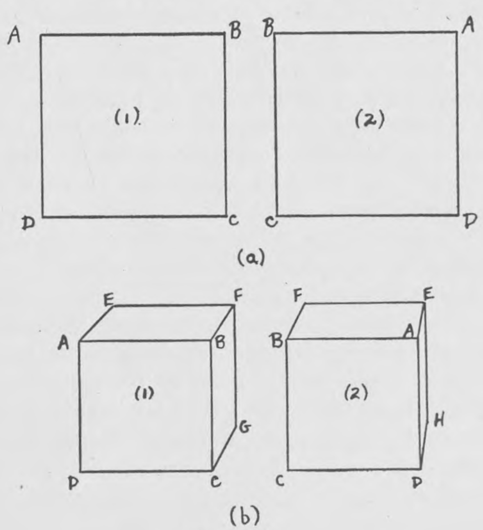


Fig. (2)

The general rule here is that: any object of dimension (X) upon being twisted while in dimension (X+1), returns to dimension (X) as a mirror image of itself. Thus, if we pushed our right hand into the fourth dimension and twisted it while there, we could withdraw it into the third dimension as a left hand. If we were taken from our space and twisted through the fourth dimension, we would return as our own mirror images. Not only would our left hands become right ones, but even our hearts would be on the other side.

Still another method of showing how a movement in higher space simplifies a movement in lower space is this: Look at figure (3) (a). It represents a line with a loop in it. Imagine that the line is a two dimensional rope. To the second dimensional man, the loop in the rope is a knot. The only way that the second dimensional man can untie this knot is to take end (d) say, and carry it in a counterclockwise direction towards (a), opening the loop finally at (c). Then upon pulling the rope taunt, he unties the knot. To us the loop is not as complicated an affair as to the two dimensional man. All we need to do to "untie" the loop is to take the rope at (b), raise it through the third dimension and drop point (b) past (c) (figure 3(b)). Then, by pulling the rope taut, we have a straight rope. We have untied the knot.

Notice that the two dimensional man can untie the knot only by manipulating **the ends** of the rope. We can untie it without touching the ends. Now consider figure (3) (c). This is a three dimensional knot tied in a rope. We must draw one end of the rope through the centre of the knot in order to untie it. By analogy, however, it is believed that a fourth dimensional man could untie this knot without touching the ends. He could take the knot at some point near its centre and twist it through the fourth dimension—thus untying it without touching the ends.

Suppose now we consider the rotation of bodies. A 2-space—for example a plane—rotates about a point. A 3-space—for example a cube—rotates about a line. By analogy then, a 4-space—for example a tesseract or cuboid—rotates about a plane.

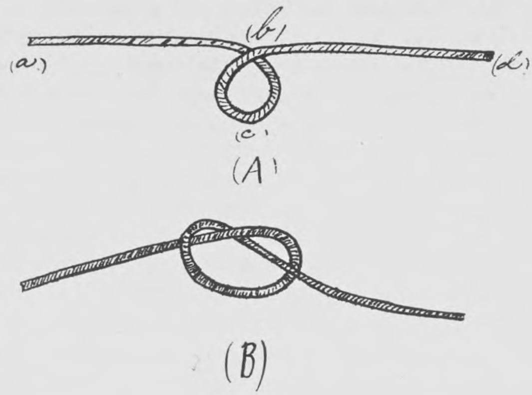


Fig. 3.

Freedom of movement in the fourth dimension too is greater than in our space. In the third dimension, the degrees of freedom of a rigid body are six: 3 translations along, and 3 rotations about 3 axes. In the fourth dimension the degrees of freedom of a rigid body are ten: 4 translations along 4 axes, and 6 rotations about 6 planes.

In all our considerations so far we have spoken of space with regard to straight lines only. Our analogies with the first, second, and third dimensional worlds were drawn on straight lines, squares and cubes. We could just as well have used the same analogies on curved spaces. Suppose a one dimensional man (A), had a friend (B), living on the same line. Suppose these two friends were separated by a distance "d" measured along the line.

Now, if the line were straight, distance "d" would be the shortest distance between A and B, but if the line were curved, that is, was in the shape of a circle, for example, the shortest distance between A and B would be that measured along the secant A B. The one dimensional man would be unaware of the secant, for it is contained in another dimension. Any higher dimensional being, however, would know that the shortest distance between A and B is not the arc AB, but the straight line AB. Similarly, curvature of space would reveal new distances in the second dimension to the three dimensional man, and again new distance in the third dimension to the fourth dimensional man. Thus, even if we consider the sun to be about 93,000,000 miles, a fourth dimensional being might consider the distance **in the fourth dimension** to be less due to the curvature of our space in the fourth dimension.

Although it is a disappointing statement to make, we must say that no three dimensional person will ever be able to detect the presence of a fourth dimensional body in our space. Consider this: Take a cone and place it point downwards in a bowl of water. At first the cone displaces a point on the surface of the water, then a small circle, then a larger circle. The circles become larger and larger till the base of the cone is reached. Then the water closes over the base of the cone. All a two dimensional person (living on the surface of the water) would see would be whatever surface the cone was displacing at the consecutive times. First he would see a point, then a series of circles which grew bigger and bigger with time, and then nothing. **He would never see the whole cone.** What have you done? You have passed a three dimensional body through two dimensional space. By analogy then, if a fourth dimensional body passed through our space, we would see it only as it appears (during the interval of its presence) in the third dimension. If a cuboid (a uniform body of the fourth dimension) passed through our space, we would see a cube. If a non-uniform fourth dimensional body passed through our space, we would see a continuously changing three dimensional body. Really all we are stating here is that we are considering time as the fourth dimension in this case. Take the case of a growing vegetable. In its initial stage it is a seed. In a few days it has changed its shape and has begun to sprout. In a few weeks we have a small vegetable—a cucumber, say. Still more time passes, and the cucumber becomes still larger. Can it be possible that this is evidence of a non-uniform fourth dimensional body passing through our space? If we could picture the changing sizes and changing shapes of the cucumber not as separate pictures, but **as separate parts of the same picture varying with time,** then we would have a complete picture of a fourth dimensional body.

Now let us try to explain certain phenomena by means of the fourth dimension. A simple statement that we could make is

that it appears that our dreams and imaginations may be fourth dimensional. We often dream of entering and leaving houses without opening or closing any doors or crawling through windows. Without apparently walking or running we often move from one room to another. We can imagine a closed box. Without opening the lid, in our imaginations we can see what is inside the box. In fact without opening the lid, we can imagine taking things out of the box. These movements are all fourth dimensional. Suppose you look at a picture of a cube as in figure (2) (b), say. Without thinking that you must turn the paper over, or that you must walk all around the cube, you can visualize the back of the cube. This is a fourth dimensional movement.

Then too, we can hazard a guess that the ether moves in fourth dimensional space. Solids (projectiles for example), tend to move in lines—that is, in one dimension. Liquids (for example water) move in two dimensions by spreading over surfaces. Gases tend to move in three dimensions (for example, air filling a vacuum). Carrying our discussion one step further, then, we may ask whether ether travels in four dimensions. There is uncertain evidence that it does. Gravitation, electricity, magnetism and light are due to stresses in or motions of the particles of the ether. Not all of the properties of the above four effects have ever been fully explained by three dimensional mathematical analysis. It is therefore believed that the ether has fourth dimensional properties and therefore the real properties of the phenomena above mentioned cannot be fully explained by third dimensional mathematics.

So far we have not stated that there is definite evidence of the fourth dimension. All we have stated is that "if" certain things were true, then we would have fourth dimensional evidence. Here then is another "if" statement: If it ever became necessary, in order to explain certain properties of an organic compound, to assume that the carbon atoms of this compound must be spaced equidistant from each other, then we would have definite evidence that the fourth dimension exists—provided that the compound under consideration has five carbon atoms. If we follow this reasoning, we shall attain the desired result. In a plane (that is in the second dimension), three points are the maximum number which can be placed equidistant from each other. In a 3-dimensional space, four points are the maximum number which can be placed equidistant from each other. By analogy, we may place no more than five points equidistant from each other in the fourth dimension. Now, if a compound has five carbon atoms, and if these five are spaced equidistant from each other, the compound must obviously be in the fourth dimension.

Now that you have given the fourth dimension a bit of consideration, you probably ask: "Of what use is the fourth dimension?"

The answer to that is fairly difficult to find, as we know so very little about the subject. In fact we are not even certain that it does exist. Needless to say, even though it doesn't exist, the fourth dimension makes us think constructively, and that alone is valuable.

In our opinion the fourth dimension has one more important use. It is the scientific garbage can. If a scientist finds that he can't explain a certain phenomenon, he brushes the situation aside by saying:

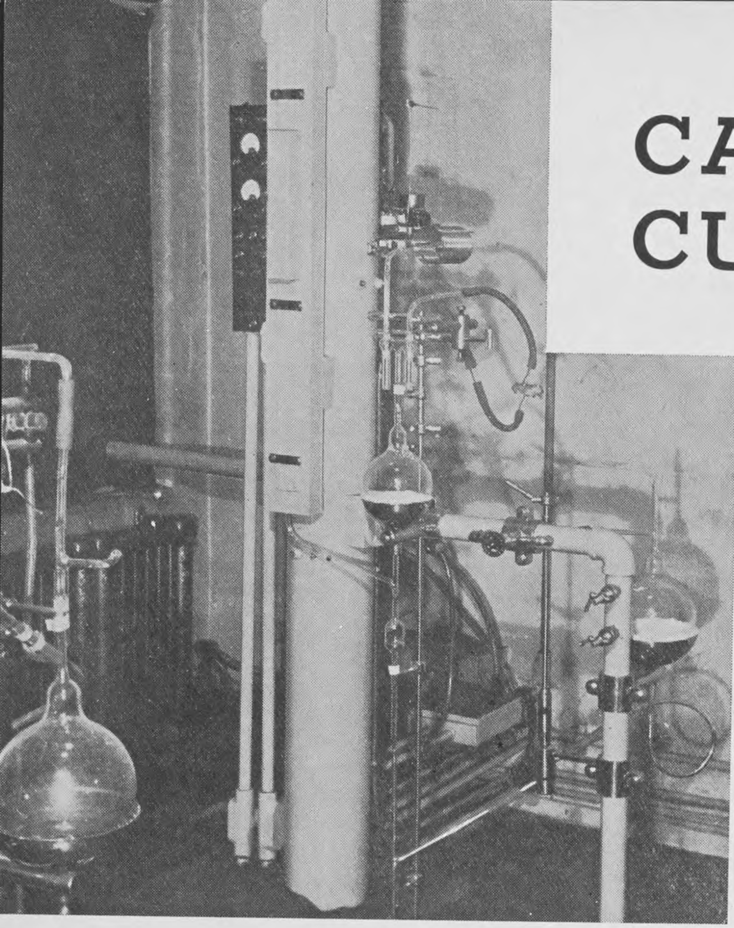
"This thing must travel in the ether."

Then he states that the ether is a fourth dimensional substance. Since we know very little about the fourth dimension., the whole situation ends in a "Question Mark."

(1) The Fourth Dimension Simply Explained, H. P. Manning; Methuen Pub. Co. (1921).
(2) The Fourth Dimension, E. H. Neville; Cambridge University Press (1921).

CANCER CURES

by S. C. FULTZ
B Sc. '41



The radon pump at the Cancer Research Institute in Winnipeg

DURING the interval of time that has elapsed between the days of the beginnings of medical science and the present-day, numerous investigations on the causes, nature, and treatment of cancer have been carried forth and have given rise to an enormous mass of data and recipes, but a small amount of actual knowledge. Recipes for treatment have constituted a very high percentage of this material since the cure for an illness is of more concern to a patient than its cause. In the process of its evolution, the treatment has adopted both non-surgical and surgical forms but the former was of much greater popularity before the advent of radium and X-ray therapy, than it is today.

Non-surgical attempts to cure cancer (1) may be divided into three periods, each period representing a number of years during which the majority of treatments were of one specific type. The first of these periods was in existence until the year 1880, and it is characterized by the extensive application, both locally and internally, of organic and inorganic chemicals. Among these were acetic acid, turpentine, and compounds of bromine, arsenic copper and lead. The net result of such treatments seems to be that sometimes temporary shrinkage of the tumor, and improvement of the general condition of the patient were noticed.

From the year 1880 to 1900, attempts were made to obtain a cure by using bacteria and their products. These attempts took the form of inoculations of numerous infectious diseases, including even syphilis, for it was believed that such diseases might actually check the growth of cancer. Some justification for this belief appeared when it was found that regression of malignant tumors took place in cancer patients who were also suffering from erysipelatis. Dr. W. B. Coley, of New York, made further investigations of this discovery and obtained remarkable results on sarcoma when he used a vaccine of killed organisms of S erysipelatis and B

Numbers in Parenthesis apply to references on Page 37.

prodigeosus. The Coley toxin received approval from the Council of the American Medical Association, but is seldom used today.

An experimental stage using such animals as rats and mice arose during the early part of the twentieth century and has extended to the present, constituting the third period of treatment. Rats were used for investigations on tumor transplants, while mice have been similarly used for tar cancer and producing a high incidence to cancer of the breast by inbreeding. The latter were also used to work out heredity problems as applied to cancer. Work done on these animals took the form of experiments on diet when vitamins were discovered. Vitamin A, when fed in excess or deficiency, was found to have no effect on carcinoma, while Dr. J. Davidson found that mice fed on a vitamin E diet were less susceptible to tar cancer than those on a deficiency. Dr. J. B. Murphy of Rockerfeller Institute, N.Y., conducted experiments on the growth controlling factor of mice. He assumed that cancer is the result of the lack of such substance in the blood serum or tissues, and believed that in order to give proper cell differentiation, this factor must be present in tissues having the greatest growth energy. Extracts of placenta and embryo skin were obtained and injected into mice with recurring breast cancers. Slight to complete regression of the tumors was noticed in about three-quarters of the cases.

Dr. Bendien (2) of Holland, found (1934) that certain unusual chemical changes occur in blood samples when they are tested with solutions of sodium vanadate. This test consists essentially of taking about 10 cc. of blood from the superficial veins of a patient, extracting the serum from it with the aid of a centrifuge, dividing this into three equal portions and subjecting each to a different treatment, as follows:

The first portion of the serum is treated as it stands. It is divided into a number of smaller parts which are set in a series of test tubes, and to each is added sodium vanadate solution of different concentrations. The test tubes are then let stand a suitable length of time, after which they are inspected for presence and amount of precipitate. The next portion is first heated, then subjected to a similar treatment. The third portion is treated first with ether, then with the vanadate solutions in a manner similar to the first. The resulting precipitates obtained from it are dissolved in dilute sodium hydroxide solution, and their amounts calculated by means of an interferometer. A comparison of the interferometer readings gives the information on which opinion is based as to the condition of malignancy or otherwise of the patient.

Apparently the underlying principle of the test seems to be that sodium vanadate causes precipitation of some of the globulin fraction of the blood serum. This is materially increased in cases of malignancy, which may be due to alternations in the amounts of calcium, potassium, magnesium, etc., and corresponding alterations in Ph value of the serum to give such. The actual chemical reaction that takes place is not fully understood.

The Bendien treatment for cancer consists mainly of rectification of the potassium or sodium imbalance found in malignant cases, restoration of the hydrogen ion concentration to the normal value, attempt to stimulate the natural defensive functions of the particular organ affected and direct attack on the malignant condition itself.

The above are only a few of the many types of non-surgical cancer treatments used in the past and present, but the treatment most widely used today is surgery and its accepted adjuvants, radium and X-rays. Today's surgeons, realizing the slow and irregular growth of cancer, judge their results on the percentage of early and late cases that are free from all signs of recurrence, five to ten years after excision or radiation. This standard has not been rigorously applied by those using non-surgical methods, and it seems that in many instances, their methods have only served to cause postponement of the more reliable form of treatment. In order to obtain a better understanding of the factors involved in radium and roentgen ray therapy, a brief survey will be made of some of the familiar physical and chemical phemonena concerned.

The property of radioactivity (3) of uranium salts was discovered by Becquerel in 1896, while trying to find a relation between fluorescent substances and X-rays. His work was followed up by Mme. Curie who consequently discovered the elements

polonium and radium, and established the fact that radioactivity is purely an atomic property independent of chemical combination. Other radioactive elements were later discovered, and a complicated mass of data arose as investigations in this field were further persued. The transformation theory of Rutherford and Soddy, 1903, served the purpose of reducing the mass to order. By this theory, atoms of radioactive elements undergo spontaneous disintegration accompanied by expulsion of an alpha or beta particle. The resulting atom has physical and chemical properties entirely different from the parent atom. Thus, uranium, on expulsion of an alpha particle becomes uranium-X_1, which in its turn expels a beta particle to become uranium-X_2, etc., until radium is formed. Radium expels an alpha particle to become radon, which in turn passes through the stages of radium A, B, C, C′, D (radiolead) E, F (Polonium), and G (lead).

Stan Fultz who is doing pre-masters work in Physics. He has worked for some time at the Man. Cancer Research Institute, where he is gaining valuable experience which will fit him to do further work in the field.

By the "activity" of a radioactive element is meant the emission of three rays known as the Alpha, Beta, and Gamma rays. The Alpha rays are composed of particles, each with a mass of 4, (similar to that of a helium atom) and containing a positive charge of two units. The Beta rays are composed of electrons, of mass 1/1850 that of a hydrogen atom and a negative charge of unity, while rays of similar type to X-rays, but of much shorter wave-length constitute the Gamma rays. The intensity of the activity of such an element falls off in an exponential manner as time goes on. If I_0 be the initial intensity, then I, the intensity after a time t is given by:

$$I = I_0 e^{-lt} \quad (1)$$

where l is a constant of transformation characteristic of the product. This law can also be expressed as:

$$N = N_0 e^{-lt} \quad (2)$$

where N_0 is the number of atoms present initially, and N the number remaining after a time t.

From equation (2):

$$\frac{-dN}{dt} = lN_0 e^{-lt}$$

The latter expression shows the rate of disintegration, or —dN/dt, to be proportional to the number of atoms of the element present. The time required for the number of atoms of this element to disintegrate to half of the original number can also be readily deduced from equation (2):

$$\ln \frac{N_0}{N} = lt_2$$

Then $\ln 2 = l\, t_2$ or $t_2 = 0.693/l$

The half-life period, (t_2) for radium is 1600 years, while that for radium emanation (radon) is 3.82 days.

The approximate relative penetrating powers of Alpha, Beta, and Gamma rays are 1, 100, 10,000 respectively. If only the Gamma rays are required, as is usually the case for biological work, a metal plate or "filter" is placed between the source and substance being radiated. This is done in order to reduce the Alpha and Beta rays to negligable intensities and still obtain appreciable Gamma radiation. The relation between the intensity of incident rays to that of rays having traversed a certain thickness of absorbing layer is given by:

$$I = I_0 e^{-ux}$$

where I_0 is the intensity of incident rays, I is the intensity of the rays after having traversed a thickness, x, of absorbing layer, and u is the coefficient of absorption for the material of the layer Since the absorption coefficient increases as the third power of the wave-length of incident rays, the intensities of soft Gamma rays, or those of longer wave-lengths are decreased a proportionately greater amount than the intensities of hard Gamma rays, or rays of short wave-length. The effect of a filter can therefore be such that the Alpha, Beta, and

soft Gamma rays are reduced to negligible intensities while the hard Alpha rays are reduced very little.

The Manitoba Cancer Relief and Research Institute possesses the equivalent of one gram of radium element, half of which is in the form of radium bromide, and the other half of radium sulphate. The sulphate, which is in the solid state, is put up in tubular platinum containers called "needles" in quantities ranging from 1 mg. to 50 mgs. The needles were prepared at the Bureau of Standards in Washington, D.C., which supplied exact information regarding the weight of radium element in each and the thickness of the container walls. The amount of filtration offered by the walls is insufficient for most radium theropy, so it has been found necessary to place the needles in brass capsules of known wall thickness to compensate for the deficiency. Brass containers of various shapes are used for special purposes. In these are placed the needles, their number being adjusted to the prescribed dosage, and their distribution such as to give as even a radiation as possible over the whole of the surface applied.

The half-gram of radium in the form of bromide, is kept a solution of about 50 cc. water and 1 or 2 drops of HC1, the latter to prevent the formation of insoluble sulphate. It is used as the source of radioactive gas (radon) but unfortunately causes other gases to be liberated too (4). The action of its rays on water causes the following transformations to take place:

(1) $2H_2O = 2H_2 + O_2$

(2) $2H_2O = H_2 O_2 + H_2$-90,000 cals.

The first reaction gives a volume of about 7.5 ccs. of gas mixture per day, while the second causes the formation of an excess of hydrogen, the hydrogen peroxide being readily soluble in the solution. Evolution of carbon dioxide is caused by the action of radiation on stop-cock grease. The actual amount of radon evolved from the bromide after equilibrium between gas formation and its disintegration has been established, is about 0.3 cu. mm. at S.T.P. Half of this is obtained 3.8 days after previous removal, while about 0.2 cu. mm. is obtained after 8 days, which is the time interval used at the Institute between successive removals.

By comparison of these volumes it can be readily seen that in order to obtain radon of sufficient concentration for medical use, considerable purification is necessary. The apparatus (5) known as an "emanation plant," or "radon pump" (see illustration), is designed to achieve this purpose. It consists mainly of the radium flask containing the radium bromide, a purification chamber, mercury piston, and a vacuum pump. The gas is transferred from one part of it to another by distribution in accordance with their relative volumes, the mercury piston acting as a doorway between the parts, which may be controlled at will. Thus, if we wish to transfer the gas mixture from the radium flask to the purification chamber, the mercury is removed from the tube connecting these two, by lowering its level and the mixture of gases allowed to diffuse through. It distributes itself in accordance with the ratio of the respective volumes of the two parts, which in this case is about 9 to 1 in favor of the system including the purification chamber. Raising the mercury level serves to trap the gases in the chamber where removal of those other than radon takes place.

The carbon dioxide is removed by potassium hydroxide, while the oxygen and hydrogen are united in a spark and the resulting water vapor absorbed by P_2O_5. Excess hydrogen is taken out by causing it to reduce copper oxide, and the water so formed is also absorbed by the P_2O_5. When the process of purification has been completed, a stop-cock is turned and the radon is forced into a calculated length of gold tubing which is sealed at one end. This tubing has an external diameter of about 1 mm. and an internal diameter of about 0.25 mm. It gives a gas-tight seal when cut with pincers, thus enabling radon "seeds" to be made to any length, depending on the strength of radiation required.

X-rays have recently become popular as a source of radiation. The type known as "extra hard" X-ray, which are used for deep therapy are obtained from tubes operating at potentials over 120,000 volts. The Winnipeg General Hospital possesses a deep therapy unit with an operating potential of 400,000 volts. The tube of this outfit is modelled after the Coolidge type but has an oil colled anode, and is immersed in oil during operation. At the Manitoba Cancer Relief and Research Institute, work is being

done on a newly designed X-ray tube which will have an operating voltage similar to the one at the General Hospital, but will be a constant evacuation type. This feature facilitates ease and speed in the replacement of parts when such is necessary, for the tube is not sealed off in a glass envelope and parts may be made locally.

Accurate measurement (6) of radiation intensity is a necessary requisite for all radiation therapy. Obviously, in order that this measurement can be made, it is necessary to define a set of practical units in terms of which it can be expressed. In the case of radium, the unit of intensity for Gamma radiation is the amount given off from one milligram of the element. Dosage, which is greatly concerned with the total amount of radiation, is therefore denoted by the number of milligram-hours required. For radon it is expressed in terms of the number of millicurie-hours, where one millicurie of the gas gives an amount of radiation equal in intensity to that obtained from one milligram of radium. The relation between the milligram and the millicurie becomes clear when we consider the fact that the majority of Gamma radiation comes from the same transformation, namely that of radium C, in both cases, and there are no Gamma rays emitted from radium during its transformation to radon.

The strength of a radon seed is found in terms of a standard one-milligram needle. The apparatus (7) designed to make this measurement consists, in essence, of a large ionization chamber and a direct current thermionic amplifier. When a seed is dropped into the chamber, the Gamma rays emitted from it cause ionization of the air contained therein. The chamber is connected in series with a 90 volt battery, so the presence of ions in it causes a small current to flow in this circuit. The current is amplified and passed through a galvanometer which gives a deflection in proportion to the number of ions produced in the chamber. The amount of ionization of air in the chamber is, in its turn, proportional to the intensity of Gamma rays emitted from the seeds, i.e., proportional to the number of millicuries present. The deflection of the galvanometer that is obtained by placing a seed in the chamber can therefore be compared to that obtained by placing a standard one milligram needle in it, and from this comparison the strength of the seed, in millicuries, is readily found.

The quantity of energy (6) contained in one quantum or photon of radiation is given by hv, where h is Planck's constant, and v is the frequency of the wave. The term "hard" applies to X-rays of high frequency, or with much energy per quantum, while the term "soft" applies to those of lower frequency and less energy per quantum. Distinction between hard and soft rays is necessary when measurement of their intensities is desired, for, in this case there is no standard source with which to compare the unknown. It is therefore essential that absolute measurements on intensities be made first, and some instrument which responds to the radiation, and is capable of reproducing readings, be calibrated in terms of these.

In the case of soft X-rays, the quantity of energy absorbed by air is directly proportional to the amount of ionization produced. The convenient unit for expressing intensity in this case can be defined in terms of the amount of ionization produced in air at S.T.P. The roentgen or R unit is such a unit, and is defined as the intensity of radiation required to produce a current of 5.56×10^{-12} amp. per cc. of air at S.T.P. Its value in ergs is also known.

In general, when a beam of X-rays strike a piece of matter some of the electrons that fly out are Compton electrons, while others are photoelectrons. The photoelectrons are electrons that have been ejected from an atom when the latter has completely absorbed X-ray quanta. The Compton electrons are ones that have been struck by an X-ray photon, and have only absorbed part of its energy, in which case the photon bounces off in the opposite direction to the electron, with a lower frequency. As the hardness of the X-rays increases, a relatively greater percentage of Compton electrons appear. They also increase as the atomic number of the substance on which they are incident is increased. The number of ions produced by hard rays are therefore proportionately less than the amount of energy absorbed. In order to minimize this deviation from proportionality, it has been found necessary to use a very narrow beam of X-rays, and a thimble-sized ionization cham-

ber which is made of a substance with the same atomic number as air.

The established units and methods of measurements of radiation permit the radiotherapist to express dosage on a quantitative basis. It is worked out from experimental data that has been collected since the beginning of radiotherapy, and which indicates the correct amount of radiation to be applied to a specific type of cancer. For instance, the number of milligram-hours required to kill 1 cc. of tissue characteristic of a certain type of tumor, may be obtained from the tables. The volume of the tumor is then measured as accurately as possible, and the dosage it requires computed from the product of this volume and the above number of milligram-hours. If radon seeds are used, the dosage in millicurie-hours is similarly found, but the strength and number of seeds required must be worked out on the respective basis of the total number of milli-curie hours that each seed is capable of delivering before its strength falls to zero, and the desired degree of distribution of radiation throughout the tumor. It is necessary to consider the total amount of radiation delivered, in this case, since radon seeds are seldom removed from the patient.

Clinical observation (8) and experimental work have proven that radium will destroy most, if not all forms of malignant cells, provided the latter be properly irradiated. Bergonie and Tribondeau, after repeated studies, were led to conclude that immature cells and cells in an active state of division are more sensitive to irradiation than cells that have already acquired their fixed adult morphologic and physiologic characters. In general, therefore, tumors that are made up of a large proportion of embryonal cells are more susceptible to irradiation than those in which the constituents are mainly adult types of tissue.

Inflammation characterizes the first effect of radium. There is a swelling of the nucleus of malignant cells, degeneration, breaking down of the nuclear capsule, swelling of the cell proper, fragmentation of the nucleus, and breaking down of the cytoplasm. The chromosomes split, spindle threads disintegrate, and cytoplasms under go rapid destruction. A fibrinous connective tissue develops in place of the malignant cells, and this contains interstices in which appear masses of chromatin, called "irradiation giant cells," which actually simulate giant cells. The fibrinous connective tissue replaces malignant cells of a tumor that has been finally destroyed by successful irradiation. Even if the tumor is not finally destroyed, the formation of this tissue is marked and important, for it frequently encapsulates remaining cancer cells. Encapsulation of these neoplastic cells by the connective tissue is undoubtedly a factor in delaying the growth of the remaining irradiated malignant cells.

The action of radiation of living tissue is assured to be that of ionization which is caused mostly by secondary electrons. Recombination of the ions, as is required for neutralization of the charges, may not take place in a manner that gives the original molecule, but may give rise to a different type of one. This chemical alteration in the cells is undoubtedly the source of the biological alterations with which we are familiar.

Cancer propaganda has for many years stressed the necessity of early diagnosis, since this has a more definite bearing on the ultimate result of the disease than any other factor. It is as important to the radiotherapist as to the surgeon, but unfortunately the disease is difficult to recognize in its early stages. Biopsy offers a safe, easy and almost certain method of diagnosis for all accessable tumors, and is employed extensively by nearly all specialists. It is of value to the radiotherapist as a method by which the susceptibility of the neonplasm to irradiation can be ascertained.

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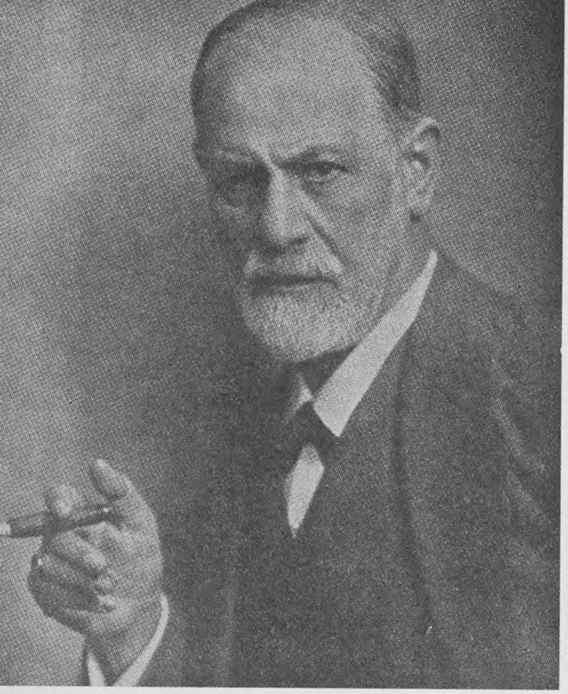

SIGMUND FREUD

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by PETER HAMPTON

EVER since the dawn of history men of genius have been recognized and admired for their ability. But not until Plato wrote his "Republic" was any systematic attempt made to study the genius with a view to setting him up as a leader of men in the respective field of endeavor in which his abilities were outstanding. Plato's labors along these lines, however, were not taken up seriously until the time of Darwin. Speculations about genius were present throughout the Middle Ages, but the matter did not go much beyond that. It was a time when the individual counted for little. With the Renaissance, and especially with the discovery of the laws of evolution, the problem of genius was set in a new light. Added to this were the beginnings of statistical techniques for a quantitative investigation of human nature. With a new orientation and a new method, differential psychologists set about in earnest to study genius.

The first psychologist to really attempt this job was Galton, who with his book on "Hereditary Genius," laid the groundwork of the psychology of genius. As the name of his monumental work implies, Galton sought the causative mainsprings of genius in heredity. Environment seemed to him of little consequence. So sure was Galton about his findings, based on the results of his studies of men of genius, that he set down the following conclusions: "No man," said Galton, "can achieve a very high reputation without being gifted with very high abilities; and few who possess these very high abilities can fail in achieving eminence." Other men followed up Galton's investigations and came to much the same conclusion. Ribot, William James, Woods, Davenport, and other psychologists concerned with the problem of genius, all declared themselves for heredity in the causation of genius. There were psychologists of a different mind, however, men like Odin, Fiske, Allen, and Ward, who just as vigorously declared themselves for nurture in explaining the causes of genius.

As has been shown recently, it was wrong to defend either heredity or environment at the expense of the other. Common sense tells us that the two are inseparable, and that both play their significant part in the causation of genius. Genius, no doubt, has its hereditary basis, but without a proper environment it cannot thrive. Who would for a moment believe that the great Einstein could have given us the laws of relativity, which have caused the re-writing of physics, if he had been born, let us say, among the primitive Ashanti in New Guinea? The fact is that a fairly plausible case can be made out for either nature or nurture in the causation of genius. The evidence can be made to support both sides.

Today we know that genius merely represents the possession in extreme degree of abilities which we all possess in varying amounts. The person who has a very high intelligence quotient is a genius; the person who has a very low intelligence quotient is an imbecile, while the person who falls halfway between these two extremes is called normal or average. Genius, therefore, is a

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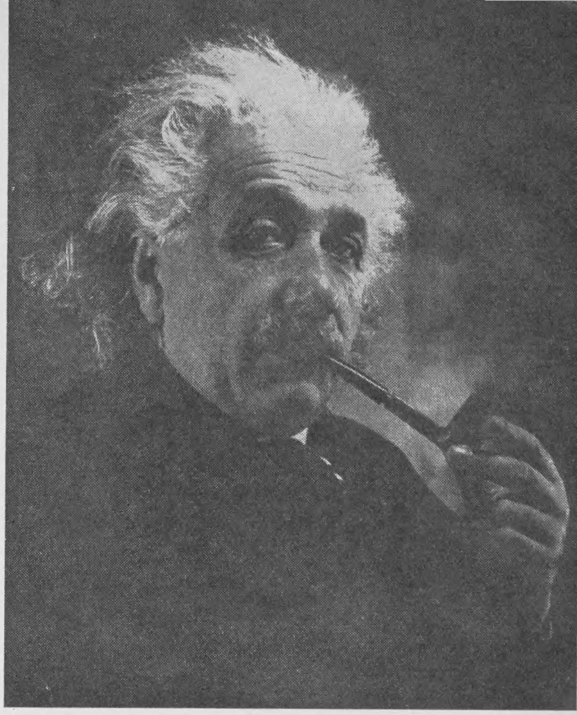
A psycholist examines the minds of some of our great creative thinkers



ALBERT EINSTEIN

relative concept, determined on the basis of arbitrary standards of quantitative measurement. And it is as such that the term is used by present day investigators of genius.

The criterion of genius most widely used today is eminence. Although there are drawbacks to the use of eminence as a criterion of genius, because there are geniuses in our midst who never obtain eminence for one reason or another, it has on the whole proved fairly satisfactory, and the best and most inclusive criterion now obtainable. The material on the basis of which the degree of eminence of the different geniuses can be determined is culled from documentary sources and biographical material. The method used in historiometry This method implies, according to Terman, "a study of the brightness of a historical character by the application to historical data of criteria of standardized measures of the mental ability of children." The method consists of two phases. First, the psychographic phase, which entails the measurement of a specific trait in different individuals, or in the same individual at different times. Second, the comparative phase, in which the data, in the form of psychographs furnish the material on the basis of which the weights of different traits may be measured. It is by such an application of mental test standards to the historical and biographical information concerning geniuses that the data for an appraisal of the brightness of the youngsters who later obtain eminence may be gained.

The most extensive study of genius in recent years has been undertaken by Catherine Cox, under the direction of Professor Terman, of Standford University. The subjects used by Miss Cox in her study consisted of two groups: A, consisting of 282 subjects, and B, consisting of 19 subjects. These were taken from a list of 1,000 subjects compiled by Cattell. Care was taken that the persons used were unquestionably eminent, that their eminence was the result of achievement and not birth, and finally, that sufficiently accurate records of these people were available on the basis of which the rating of the early mental ability was made.

The geniuses studied lived in the period from 1450-1849, and represented a number of different nationalities. It was found that 18 per cent. of the geniuses examined had obtained eminence in the field of imaginative writing. They were poets, novelists, and dramatists. Next came statesmen and politicians, representing 15 per cent. of the total group. Another 15 per cent. consisted of a second group of writers, including essayists, critics, scholars, and historians. The rest of the geniuses represented were made up as follows: scientists 14 per cent., soldiers 10 per cent., religious leaders 8 per cent., philosophers 8 per cent.. artists 5 per cent., musicians 4 per cent., and revolutionary statesmen 3 per cent.

It seems that the geniuses who live longest have the best chance of becoming eminent. Thus the most eminent philosophers, scientists, scholars, statesmen, and religious

leaders live long lives. Eminent imaginative writers, artists, soldiers, and especially revolutionary statesmen and musicians are on an average not long-lived. It may be that people in the latter fields of endeavour do not require so long a life to become eminent as the former; on the other hand, it may also be that an early death, especially if death comes under spectacular circumstances, is conducive to eminence. Four-fifths of the geniuses studied came from the professional, semi-professional, and higher business classes. One-fifth came from the lower business and skilled labour, semi-skilled labour, and unskilled labour classes.

With regard to each of the geniuses studied, the following points were brought out: (1) name, dates, and field; (2) work done; (3) chronology; (4) ancestry and family; (5) development to age 26; (6) characterization; and (7) the basis of eminence. The information obtained for the data of the study includes the following factors: (1) the earliest period of instruction; (2) the nature of the earliest learning; (3) the earliest productions; (4) the first reading; (5) the first mathematical performance; (6) typical precocious activities; (7) unusually intelligent applications of knowledge; (8) the recognition of similarities or differences; (9) the amount and character of the reading; (10) the character of various interests; (11) school standing and progress; (12) early maturity of attitude or judgment; (13) the tendency to discriminate, to generalize, or to theorize; and (14) family standing.

On the basis of the information thus obtained, the behavior and performance of the geniuses studied was rated with respect to intelligence. The norms and standards for intelligent behavior at the various age levels, which have been established by a tremendous amount of mental testing, were used as the criteria on the basis of which the intelligence of the geniuses was arrived at. The intelligence ratings were expressed in terms of the I.Q., i.e., the ratio of mental age to chronological age. For example, if the occupational status of parents is used as a standard for rating the intelligence of their children, those whose parents fall into the professional level, may be given an average I.Q. of 120, (100 is average for the general population); those whose parents fall into the semi-professional and higher business levels, may be given an average I.Q. of 110; while those whose parents fall into the lower business and skilled labour levels, may be given an average I.Q. of 100.

Again, the norms of work in school may also be used for rating the intelligence of men and women. The youngster who does average work in an average school at an average age, is likely to have an average I.Q. of 100. Secondly, the youth who attends a standard high school and does superior work most likely has an I.Q. of about 120. Finally, the youth who attends a superior high school and does exceptionally well, most likely has an I.Q. of about 140. By using the norms and standards established for different kinds of behavior, as exhibited in the 14 instances mentioned above, as criteria, the psychologist can estimate the true I.Q. of the individual under consideration fairly accurately. He rates the individual on as many of the 14 points above mentioned as he can get information on and then averages his ratings. The outcome represents the intelligence quotient or brightness of the person rated.

Nationality does not seem to be related to intelligence in any way. The average I.Q.'s of the geniuses belonging to different nationalities are more or less the same. There are individual differences, of course, but as a group no appreciable difference is observable. There is, however, a definite relation between I.Q. and the fields in which the different geniuses became eminent. The average I.Q. of the eminent philosophers and writers is highest, about 150. The lowest average is scored by the eminent soldiers, musicians, and artists. The average I.Q. for the soldiers is about 108, while that for the musicians and artists is about 127. The religious leaders, statesmen, and scientists fall in between the soldiers and the philosophers.

The following list presents the estimated intelligence quotients for a number of the more familiar geniuses studied by Catherine Cox and her assistants:

Name—	Field	I.Q.
1. Cervantes	Poet and Novelist	105
2. Drake	Naval Hero	105
3. Copernicus	Astronomer	105
4. Faraday	Chemist and Physicist	105
5. Raphael	Painter	110
6. Cromwell	General and Statesman	110
7. Rembrandt	Painter	110
8. Jackson	U.S. President	110
9. Cortez	Soldier	115
10. Goldsmith	Poet and Novelist	115
11. Luther	Religious Leader and Reformer	115

12.	Fielding	Novelist and Dramatist	120
13.	Richelieu	Statesman	120
14.	Van Dyck	Painter	120
15.	Garibaldi	Soldier	120
16.	Bolivar	General and Statesman	125
17.	Dryden	Poet and Dramatist	125
18.	Bach	Composer	125
19.	Lincoln	U.S. President	125
20.	Washington	U.S. President	125
21.	Nelson	Admiral	125
22.	Spinoza	Philosopher	130
23.	Moliere	Dramatist	130
24.	Newton	Mathematician	130
25.	Rousseau	Philosopher	130
26.	Beethoven	Composer	135
27.	Darwin	Naturalist	135
28.	Kant	Philosopher	135
29.	Wagner	Composer	135
30.	Napoleon	Emperor	135
31.	Hobbs	Philosopher	140
32.	Carlyle	Essayist and Historian	140
33.	Dumas	Dramatist and Novelist	140
34.	Michelangelo	Sculptor and Painter	145
35.	Galileo	Physicist and Astronomer	145
36.	Dickens	Novelist	145
37.	Disraeli	Prime Minister	145
38.	Emerson	Essayist	145
39.	Milton	Poet	145
40.	Hegel	Philosopher	150
41.	Mendelssohn	Composer	150
42.	Longfellow	Poet	150
43.	Scott	Novelist	150
44.	Tennyson	Poet	155
45.	Hume	Philosopher	155
46.	Pope	Poet	160
47.	Wolsey	Cardinal	165
48.	Voltaire	Writer	170
49.	Coleridge	Poet	175
50.	Pascal	Geometrician	180
51.	Macauley	Essayist	180
52.	Grotius	Jurist	185
53.	Leibnitz	Philosopher	185
54.	Goethe	Poet	185
55.	Mill, J. S.	Philosopher	190

These I.Q.'s were estimated on the basis of the information about the geniuses between the time of their birth and 17th year. Another estimate, based on information referring to the period between the 17th and 26th year of life, raises the I.Q. for most of the subjects.

Due to the fact that a number of the I.Q.'s of the geniuses studied have been arrived at through rather scanty information, they cannot be regarded as completely adequate. In those cases where the information is limited, most of the cases obtaining the lower I.Q.'s on the list, the true I.Q. is probably somewhat higher. The cases indicative of high I.Q.'s, on the other hand, represent fairly accurately the I.Q. of the geniuses considered. The reliabilities for the estimated I.Q.'s vary in direct proportion with the information available for the individual concerned.

A high intelligence, however, is not sufficient cause for a person to attain eminence or become a genius. If it were, such men as Copernicus and Faraday, with an estimated I.Q. of 105, and such men as Cromwell and Rembrandt, with an estimated I.Q. of 110, would never become eminent. Personality, opportunity, and many other factors play their part in providing one with a place in the sun.

What are some of the personality factors that distinguish the genius from the ordinary person? The following traits seem to be indicative of achievement in the future: (1) desire to excel; (2) tenacity of purpose; (3) perseverance in the face of obstacles; (4) mental work bestowed on special interests; (5) depth of apprehension; and (6) originality of ideas. In all of these traits the future genius rates high. The emotional aspects of personality are the same with the genius in general as they are with the unselected average individual.

Eminence in one field differs from that in another. The following are examples of the most distinctive traits of the geniuses studied in three different fields of endeavour. The eminent artists studied by Catherine Cox and her assistants got an average I.Q. of 127. They are characterized by a high degree of aesthetic feeling, a strong desire to excel, a confident belief in their own powers, originality of ideas, persistence of motive, and enjoyment of work with distant objects or goals in view. The imaginative writers, i.e., the poets, novelists, and dramatists studied obtained an average I.Q. of 150. They are particularly characterized by a high degree of imaginativeness, aesthetic feeling, and amount of work spent on pleasures. They desire to be leaders, rate their own special talents correctly, have a strong memory, originality of ideas, and keen observation. They do not rate high in sound common sense, and the degree to which action and thought are dependent on reason. Their actions are dictated more by emotional impulses than rational considerations.

The average I.Q. of the musicians is 130. They show a high degree of aesthetic feeling and desire to excel; they believe in their own powers, have originality of ideas, bestow a fair amount of mental work upon pleasures, work toward a distant goal, show persistence in the face of obstacles, and exhibit a quiet determination.

"In strength or force of character," says Catherine Cox, "the religious leaders and the revolutionary statesmen come highest and the musicians lowest; in intellectual traits, the philosophers and scientists rate highest

and the fighting soldiers lowest; on traits of self, statesmen and revolutionary statesmen rate highest and artists and statesmen soldiers lowest; on activity traits, the fighters are highest, with the writers lowest; on social traits, the soldiers rate highest and the arists lowest; in balance, statesmen rate highest and revolutionary statesmen and writers lowest; in persistence of motive, the religious leaders rate highest and writers lowest; in the emotional traits the deviations are slight."

Genius is thus a complex mixture. It is evident from the facts marshalled in the preceding paragraphs that heredity accounts for a great deal in opening up a road to eminence. A child born the son or daughter of a general, a scholar, or a statesman has an infinitely better chance to become eminent than the son or daughter of a business man or a skilled labourer. However, a favourable ancestral background is not a sufficient cause for a person to become a genius. Often the son of a genius turns out to be an average individual. On the other hand, men of low social and economic rank have become geniuses. Kant's father was a strap-maker, Bunyan's a tinker, and Carlyle's a mason.

A favorable early environment helps the individual towards eminence. Thus, superior education and inspiring social contacts are of great value. The training received by Pitt, the younger, John Quincy Adams, Mozart, and Michelangelo, undoubtedly did much to establish the eminence these men were to know in later life. On the other hand, the early environment of a Lincoln, a Faraday, or a Bluecher was decidedly unfavourable to success, and yet these men succeeded in spite of it. Thus, neither favourable hereditary ancestry nor a favourable early environment is sufficient assurance of success.

The geniuses considered all rated fairly high in intelligence, and this intellectual behavior was evidenced very early in life. We learn, for instance, that Voltaire "wrote verses from his cradle," that Mozart "composed a minuet at 5," that Goethe "at 8 produced literary work of adult superiority." In many cases later achievement was thus foreshadowed in early behavior. But again, even if an individual had an I.Q. of 200 that would not be a guarantee that he would become a genius. Faraday with an I.Q. of 105, and Rembrandt with an I.Q. of 110, became eminent in spite of their comparatively low rating in intelligence.

To the general ingredients of genius, namely, a favourable hereditary background and early environment, and a high I.Q., must be added persistence of motive and effort, confidence in oneself and one's abilities, and great strength or force of character. Only a combination of all of these traits in varying degrees, plus "superior general powers of persistent interest and great zeal combined with rare special talents" will herald the coming genius, who proves himself already in childhood to be of superior intelligence, talents, and traits of character. The gifted youth who today possesses "a combination of the highest degree of general ability, special talent, seriousness of purpose, and indomitable persistence" may well be the genius of tomorrow.

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